SYSTEMATICS OF THE TRIBES SCYMNINI AND STETHORINI (COLEOPTERA: COCCINELLIDAE) FROM SOUTH INDIA

by

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(2014-21-111)

THESIS

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2018

DECLARATION

I, Vidya C.V., hereby declare that this thesis entitled **"Systematics of the tribes Scymnini and Stethorini (Coleoptera: Coccinellidae) from south India"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that the thesis entitled **"Systematics of the tribes Scymnini and Stethorini (Coleoptera: Coccinellidae) from south India"** is a record of research work done independently by **Ms. Vidya C. V.** (2014-21-111) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Introduction

1. INTRODUCTION

Coccinellidae Latreille, 1807 is the largest family in the superfamily Coccinelloidea Latreille, 1807 of the order Coleoptera, with around 6000 described species (Robertson *et al.*, 2015). These are called 'lady beetles', but are also commonly known as ladybugs (American) or ladybirds (Britain). The name "ladybird" is usually dedicated to the Virgin Mary (Gordon, 1985), as the beetle's bright red shell, which is not too dissimilar from the red cloak of Mary.

Coccinellids are recognised by the compact rounded body varying from circular to elongate oval, convex dorsal side and flat ventral side, short clubbed antennae and presence of post coxal line on the first abdominal ventrite. Tarsi are usually cryptotetramerous, but rarely true trimerous or true tetramerous. Lady beetles are ecologically and morphologically diverse and exhibit a wide range of food habits that include phytophagy, mycophagy and predation. Most species of coccinellids are predaceous in nature and the preferred prey for this group of insects belong to sternorrhynchan Hemiptera *viz.*, aphids, adelgids, mealybugs, psyllids, and other soft bodied insects and also mites (Vandenberg, 2002). Coccinellids are of considerable economic importance as these have been utilized successfully in the biological control programmes. The classical example is the successful introduction of vedalia beetle, *Rodolia cardinalis* (Mulsant) from Australia to many parts of world to control cottony cushion scale, *Icerya purchasi* Maskell.

Sasaji (1968) recognised six subfamilies *viz.*, Chilocorinae Mulsant, 1846, Coccidulinae Mulsant, 1846, Coccinellinae Latreille, 1807, Epilachninae Mulsant, 1846, Scymninae Mulsant, 1846 and Sticholotinae Weise, 1901. Scymninae, one of the species rich subfamily of Coccinellidae, comprises of five tribes *viz.*, Stethorini Dobzhansky, 1924; Scymnini Mulsant, 1846; Aspidimerini Mulsant, 1850; Hyperaspidini Mulsant 1846 and Ortaliini Mulsant, 1850. Recently, based on the molecular and morphological evidences Seago *et al.* (2011) formally revised the subfamily classification of Coccinellidae, which comprised of two subfamilies: Microweiseinae Leng 1920 and Coccinellinae Latreille, 1807 (*sensu* Slipinski,

2007). As a result tribes, Scymnini and Stethorini were considered as composite tribes under the tribe Coccidulini Mulsant, 1846 of subfamily Coccinellinae.

Tribe Scymnini and Stethorini include members which are very small, pubescent and similar in appearance. Both these tribes are cosmopolitan with worldwide distribution. Adults and grubs of Scymnini are predaceous on aphids, mealybugs, scales, whiteflies etc. *Cryptolaemus montrouzieri* Mulsant, 1853 of tribe Scymnini is an important biocontrol agent against mealybugs and scales and is rated second to *Rodolia cardinalis* (Mulsant) with respect to its success in the introduced parts against various mealybugs (Poorani *et al.*, 2014). Of the 18 genera under Scymnini (Nedved and Kovar, 2012), the most predominant genus is *Scymnus* Kugelann, 1794 with more than 800 described species all over the world (Chen *et al.*, 2013). Indian subregion is represented by 88 species of Scymnini under six genera, of which 21 species belonging to six genera are reported from south India (Poorani, 2002; 2015a).

Tribe Stethorini includes very small pubescent black beetles with yellow appendages. They are unique among Coccinellidae in being specialist on mites belonging to the family Tetranychidae and Tenuipalpidae. Stethorini is represented by two genera *Stethorus* Weise and *Parastethorus* Pang and Mao, of which *Stethorus* is the predominant one, with about 95 species known from all over the world (Li *et al.*, 2013; Poorani, 2017). Many species of Stethorini have been introduced into different parts of world because of their potential as biocontrol agents of spider mites (Biddinger *et al.*, 2009). Indian Stethorini is represented by nine species under two genera and seven species have been reported from south India so far (Poorani, 2002; 2017).

Coccinellid fauna of Indian subcontinent is rich and diverse. The pioneer works of Mulsant, Crotch, Sicard, Weise and Gorham contributed greatly to the understanding of coccinellid fauna of Indian subregion. The most salient work on Indian subcontinental coccinellid fauna was by Dr. A. P. Kapur, the former Director of Zoological Survey of India. In a series of publications, he described many new species of Scymnini and Stethorini. Other significant contributors include

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Bielawski, Miyatake, Sasaji, Canepari and Booth (Poorani, 2002). Significant contributions on Scymnini and Stethorini have recently been published from China (Chen *et al.*, 2012, 2013, 2014, 2015a, 2015b, 2015c, 2016a, 2016b; Li *et al.*, 2013), Australia (Slipinski *et al.*, 2012; Poorani *et al.*, 2014) and India (Poorani, 2002; 2015a; 2017).

There is a strong need to revise the genera and species of the tribe Scymnini of Indian region. Identification of most of the Scymnini of Indian region into species is found to be difficult due to the paucity of representative collections covering the entire region and lack of access to types (Poorani, 2015a). Tribe Stethorini of Indian region is also poorly studied. As of now, there is no systematic study on the tribes Scymnini and Stethorini from south India, which is very important as these groups include the predators of sucking pests of agriculturally important crops. The cryptic nature of adults of Stethorini makes it difficult to identify at species level and hence diagnostic taxonomy by molecular barcoding methods were suggested for species of Stethorini (Biddinger *et al.*, 2009).

Considering the above, the present study on "Systematics of the tribes Scymnini and Stethorini (Coleoptera: Coccinellidae) from south India" was carried out with the following objectives.

1. To study the taxonomy of the tribes Scymnini and Stethorini associated with sucking pests in different agricultural ecosystems of south India.
2. To prepare a key for the identification of species of Scymnini and Stethorini.
3. To generate DNA barcode for different species of Stethorini collected during the study.

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Review of literature

2. REVIEW OF LITERATURE

The lady beetles belonging to the coleopterous family Coccinellidae, comprises approximately 6000 described species in 360 genera and 42 tribes (Vandenberg, 2002). These are economically important as most of them are predaceous on aphids, scale insects and other soft bodied homopterans, thrips, mites and even on early instar lepidopterans and hence beneficial (Poorani, 2002). The spectacular success of introduction of a coccinellid beetle, *Rodolia cardinalis* (Mulsant) from Australia to California to combat the cottony cushion scale, *Icerya purchasi* Maskell, 1878 (Monophlebidae: Hemiptera) in citrus was a landmark in classical biological control programmes (DeBach, 1964).

2. 1. Classification of the family Coccinellidae

The classification of the Coccinellidae began with Carolus Linnaeus in the mid 1700's (Gordon, 1985) and he described 36 species under the genus *Coccinella* in 1758 (Sasaji, 1971). The family name "Coccinellidae" was coined by Latreille (1807). Redtenbacher (1844) was the first to propose the subdivision of the family Coccinellidae by recognising two groups *viz*., aphidophagous and phytophagous based on the feeding habit. Mulsant (1846) proposed the first system of classification, to which he gave the group name "Securipalpes" (=Coccinellidae) and he produced a world monograph of the Coccinellidae and established the system of classification (1850) for all the coccinellids of the world. The two major divisions proposed by him were "Gymnosomides" and "Trichosomides" based on the presence or absence of the dorsal pubescence. This scheme was considered very artificial and later abandoned. However, many of his groups have been recognized in the later systems, and it can be said that his work was an epoch making contribution at that time (Sasaji, 1971). Interestingly, the results of the molecular studies on the phylogeny of subfamilies of Coccinellidae after 150 years (Magro *et al*., 2010) showed that the beetles in the terminal clade were glabrous, while the species at the base of the tree were hairy. Though, this accords with Mulsant's

classification, further analysis is needed to test the hypothesis that pubescence is a primitive character.

Crotch (1874) revised Mulsant's classification and the presence of dorsal pubescence was omitted from the key characters. He established seven subfamilies under the family Coccinellidae: Coccinellidae, Thytthaspides, Chilocorides, Hyperaspides, Scymnides, Exoplectrides and Rhizobiides. Later, Chapuis (1876) classified Coccinellidae into two major subdivisions, "Aphidiphages" and "Phytophages" and again "Aphidiphages" into 13 groups *viz*., Hippodamiites, Coccinellites, Discotomites, Cariites, Poriites, Ortaliites, Scymnites, Bucolites, Coccidulites, Chnoodites, Hyperaspites, Cranophorites and Chilocorites. Weise refined the coccinellid classification in a series of papers published from 1879 to 1925. He divided the Coccinellidae (1879) into two major groups, "Coccinellidae aphidophagae" and "Coccinellidae phytophagae". His studies on Ceylonese Coccinellidae (1900) was important for the subdivisional study of the family. Weise was the first coccinellid taxonomist to realize that male genitalia could be used to distinguish species (Gordon, 1985).

The two excellent works published by the end of 19th century were by Ganglbauer (1899) in Europe and Casey (1899) in North America. Ganglbauer proposed three subfamilies, Epilachninae, Lithophilinae and Coccinellinae, whereas Casey emphasized the separation of the family Coccinellidae into aphidophagous and phytophagous and arranged them in sixteen tribes without recognizing the subfamilies. Sicard (1907, 1909) investigated on Madagascan Coccinellidae and arranged them as Coccinellidae phytophagae, Coccinellidae aphidiphagae and Pseudococcinellidae.

Korschefsky (1931, 1932) arranged all the Coccinellidae of the world into three subfamilies: Epilachninae (10 genera), Lithophilinae (one genus) and Coccinellinae (234 genera). This remains the single most useful taxonomic publication for coccinellid specialists. Many authors (Bielawski, 1959; Fursch, 1960; Kapur, 1963; Zaslavskij, 1965) followed Korschefsky's system of classification with slight modifications.

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Another landmark in the coccinellid classification was the publication of "Phylogeny of the family Coccinellidae (Coleoptera)" by Sasaji (1968). He established a new system from the phylogenetic point of view, based on the comparative morphology of both larvae and adults. He recognized six subfamilies and this system was widely accepted and has remained the primary reference for the family. The arrangement is as follows.

Subfamily	**Tribes**
Sticholotinae Weise, 1901	Sukunahikonini; Serangiini Blackwelder, 1945; Sticholotini Weise, 1901; Shirozuellini Sasaji, 1967
Scymninae Mulsant, 1846	Stethorini Dobzhansky, 1924; Scymnini Mulsant, 1846; Aspidimerini Mulsant, 1850; Hyperaspini Mulsant 1846; Ortaliini Mulsant, 1850
Chilocorinae Mulsant, 1846	Telsimiini Casey, 1899; Platynaspini Mulsant, 1846; Chilocornini Mulsant 1846
Coccidulinae Mulsant, 1846	Lithophilini; Coccidulini, Mulsant, 1846; Exoplectrini Crotch, 1874; Noviini Mulsant, 1850
Coccinellinae Latreille, 1807	Coccinellini Latreille, 1807; Psylloborini
Epilachninae Mulsant, 1846	Epilachnini, Mulsant 1846

(Tribes Scymnillini Casey, 1899; Cranophorini Mulsant, 1850; Azyini Mulsant and Discotomini Mulsant, 1850 were not treated)

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Chazeau *et al.* (1989) retained Sasaji's six subfamilies with modification in the arrangement of tribes. Duverger (1989; 2001) recognised an additional subfamily, Hyperaspidinae for Hyperaspidini plus Brachiacanthini Mulsant, 1850 and Gordon (1994) elevated the tribes Azyini and Exoplectrini to subfamiliy, Azyiinae and Exoplectrinae Crotch 1874. Kovar (1996) established a new subfamily Ortaliinae, which included the tribes Ortaliini (previously in Scymninae) and Noviini (previously in Coccidulinae). Fursch (1996) followed Kovar's classification of subfamilies by including seven subfamilies within the family Coccinellidae. Nedved and Kovar (2012) later included two more subfamilies, Exoplectrinae and Microweiseinae Leng, 1920.

Slipinski (2007) suggested a system based on two subfamilies, Microweiseinae and Coccinellinae. Recently, Seago *et al.* (2011), based on morphological and molecular evidences, revised the subfamily classification of Coccinellidae to comprise of two subfamilies: Microweiseinae and Coccinellinae (*sensu* Slipinski, 2007). The remaining groups for which monophyly was supported were designated as tribes within Coccinellinae while the tribes whose monophyly was not adequately tested were retained.

According to this classification, the tribes, Scymnini and Stethorini which were earlier recognized under the subfamily Scymninae, were treated as a part of the composite tribe Coccidulini Mulsant, 1846 under the subfamily Coccinellinae. However, the classification of Coccinellidae proposed by Sasaji (1971) and Kovar (1996) is followed in the present study. Hence Scymnini and Stethorini are treated as tribes under the subfamily Scymninae.

2. 2. Systematic position of the family Coccinellidae

Many authors have expressed various viewpoints regarding the classification of Coleoptera and phylogenetic relationships among the families. However, in almost all of the systems, family Coccinellidae was placed in the superfamily Cucujoidea or Clavicornia (=Diversicornia) in the suborder Polyphaga (Sasaji, 1971). The current classification recognises 37 families under Cucujoidea

(Leschen *et al.*, 2005; Leschen and Slipinski, 2010; Lord *et al.*, 2010; Cline *et al.*, 2014).

Sasaji (1971) observed the difficulty to construct the phylogenetic tree of the Cucujoidea and to find the truly recognised evolutionary origin of the Coccinellidae. Slipinski and Pakaluk (1991) opined that Cucujoidea is a presumed artificial assemblage of beetles that have a similar appearance that could not be placed satisfactorily elsewhere. This group was established for convenience and served as the largest taxonomic dumping ground among the super families of Coleoptera. Among the six cucujiform super families, Cucujoidea is regarded as the most problematic with respect to classification and no synapomorphies supporting its monophyly has been identified (Leschen *et al.*, 2005; Leschen and Slipinski, 2010; Robertson *et al.*, 2008).

Crowson (1955) was the first to recognise a group of beetles related to Cerylonidae, which he termed as Cerylonid group or Cerylonid Series (C.S.). It includes a cluster of highly derived families within Cucujoidea characterised by some common features. The Cerylonid Series comprises of around 10,000 species within 660 genera of nine families *viz.*, Alexiidae, Bothrideridae, Cerylonidae, Coccinellidae, Corylophidae, Discolomatidae, Endomychidae, Latridiidae and Akalyptoischiidae (Lord *et al.*, 2010; Robertson *et al.*, 2015).

Robertson *et al.* (2008) conducted a phylogenetic study based on 18S and 28S rDNA for 16 outgroup taxa and 61 C.S. ingroup taxa, representing seven C.S. families and 20 subfamilies. The analysis supported the paraphyly of Cucujoidea and confirmed the monophyly of C.S. and family Coccinellidae.

Although, the monophyly of C.S. is supported by morphological and molecular evidences, the closest relative of Coccinellidae is not clear. Morphological analysis supported the hypothesis that Coccinellidae showed close affinity to Corylophidae and Endomychidae (Sasaji, 1971) and to the clade comprising of Endomychidae plus Alexiidae (Slipinski and Pakaluk, 1991). But these hypotheses were highly intuitive and not based on formal phylogenetic studies.

The phylogenetic study of Robertson *et al.*, (2008) also could not identify a consistent, well-supported sister group to Coccinellidae. The parsimony analysis showed sister group relationship between Leiestine (Endomychidae) and Coccinellidae and the Bayesian analysis placed Coccinellidae unresolved with a clade comprising most of Endomychidae or Anamorphinae plus Corylophidae clade.

Robertson *et al.* (2015) formally recognized the Cerylonid Series as a new superfamily Coccinelloidea by the comprehensive analysis of cucujoid taxa with DNA sequence from eight genes (four nuclear, four mitochondrial) for 384 coleopteran taxa including exemplars of 35 families and 289 genera of Cucujoidea. Superfamily Coccinelloidea comprised of 15 families, which are monophyletic. The six additional subfamilies recognised under Coccinelloidea other than subfamilies within C.S. are Teredidae, Euxestidae, Murmidiidae, Anamorphidae, Mycetaeidae and Eupsilobiidae.

2. 3. Phylogeny of family Coccinellidae

Coccinellidae is a monophyletic group which is well supported by morphological and molecular evidences. But the higher level phylogenetic relationships within coccinellid taxa is poorly known. The first attempt to address phylogenetic hypotheses of the relationships between Coccinellidae subfamilies was by Sasaji (1968, 1971). He recognised and analysed six subfamilies under Coccinellidae. According to his hypothesis, the subfamily Sticholotidinae is the most 'primitive' group diverging from the rest of coccinellids at the basal splits. The two other major lineages proposed were the one including the subfamilies Chilocorinae and Scymninae, and the other including Coccidulinae, Epilachninae and Coccinellinae. In the second group, Coccidulinae was considered as the sister group to Coccinellinae plus Epilachninae branch. Sasaji's hypothesis was modified by Kovar (1996) by recognising one more subfamily, Ortaliinae which he considered as the sister taxon to Coccinellinae and Epilachninae. Coccidulinae was moved to Chilocorinae plus Scymninae branch and proposed as sister group to

Chilocorinae and Scymninae. But these hypotheses were intuitive and not generated by formal study.

Yu (1994) performed a cladistics analysis using adult and larval characters of 21 coccinellid exemplars. This analysis was problematic and resulted in conflicting topologies.

Robertson *et al.* (2008) first attempted to test the monophyly of the C.S. and its constituent families and subfamilies and to find out the phylogenetic relationships among the lineages based on molecular sequence data. The analysis confirmed the monophyly of Coccinellidae and supported the monophyly of coccinellid subfamilies Coccinellinae, which comprise the typical 'ladybugs' and Epilachninae which comprise phytophagous members of the family (Vandenberg, 2002). The paraphyly of Chilocorinae and Scymninae are characterised by strong morphological or behavioural synapomorphies. Similar results were observed by the phylogenetic analysis of 62 taxa by Giorgi *et al.* (2009), which demonstrated the monophyly of family Coccinellinae and Epilachninae and paraphyly of Sticholotidinae, Chilocorinae, Scymninae and Coccidulinae.

Phylogenetic relationships within the family Coccinellidae based on the analysis of five genes: the 18S and 28S rRNA nuclear genes and the mitochondrial 12S, 16S rRNA and cytochrome oxidase subunit I (COI) genes were studied by Magro *et al.* (2010) who found that subfamily Coccinellinae was monophyletic, while, Coccidulinae, Epilachninae, Scymninae and Chilocorinae were paraphyletic. This study also demonstrated that the cluster *Henosepilachna-Epilachna*, the subfamilies Ortaliinae and Sticholotidinae and the genus *Stethorus* (Scymninae) occupied the basal positions.

2. 4. Subfamily Scymninae Mulsant, 1846

The subfamily Scymninae was erected by Mulsant (1846) with *Scymnus* Kugelann, 1794 as its type genus. He erected the group "Scymniens" under "Trichosomides" which includes hairy coccinellids. The name Scymninae was first used by Della Beffa in 1912 (Vandenberg, 2002). Later, Sasaji (1968) defined the

subfamily Scymninae which comprised of five tribes Stethorini, Scymnini, Aspidimerini, Hyperaspini and Ortaliini. Further, Sasaji (1971) added two more tribes, Scymnillini and Cranophoroni. The tribes Cryptognathini Mulsant, 1850 and Selvadiini Gordon, 1985 were established by Gordon (1971, 1985) as members of Scymninae. Chazeau *et al.* (1989) proposed all the recognised tribes so far under Scymninae in his classification. Duverger (1989) treated Hyperaspidini into Hyperaspidini and Brachiacanthini (as Hyperaspini and Brachiacanthadini). Kovar (1996) modified Chazeau classification of Scymninae by separating the tribes Cranophorini and Ortaliini to other subfamilies and accommodating the Brachiacanthini. He preferred to use the name Pentiliini Mulsant,1850 rather than Cryptognathini in his classification. Gordon (1999) provided the evidences for the distinction of *Diomus* from *Scymnus* and allied genera and erected the new tribe Diomini Gordon, 1999 which comprised of *Diomus* and four other Neotropical genera. Fursch (1996) included ten tribes: Aspidimerini, Stethorini, Scymnini, Diomini, Scymnillini, Selvadiini, Hyperaspidini, Brachiacanthadini, Pentiliini and Cryptognathini under Scymninae. Nedved and Kovar (2012) added one more tribe, Platynaspidini Mulsant, 1846 to the subfamily Scymninae.

A comparison of the tribes under Scymninae by different authors are summarised (Table 1.).

Table 1. Proposed classifications of subfamily Scymninae

Sasaji, 1971	Chazeau *et al.*, 1989	Kovar, 1996	Fursch, 1996	Nedved and Kovar, 2012
Cranophorini	Aspidimerini	Scymnillini	Aspidimerini	Aspidimerini
Ortaliini	Stethorini	Scymnini	Stethorini	Brachiacanthini
Scymnillini	Scymnini	Aspidimerini	Scymnini	Cryptognathini
Scymnini	Scymnillini	Selvadiini	Diomini	Diomini
Aspidimerini	Selvadini	Hyperaspidini	Scymnillini	Hyperaspidini
Hyperaspidini	Cranophorini	Brachiacanthini	Selvadiini	Peniliini
Stethorini	Hyperaspidini	Stethorini	Hyperaspidini	Platynaspidini

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	Ortaliini	Cryptognathini (as Pentiliini)	Brachiacanthadini	Scymnillini
	Cryptognathini		Pentiliini	Scymnini
			Cryptognathini	Selvadiini
				Stethorini

Slipinski (2007) proposed a new system of classification which comprised only two subfamilies, Microweiseinae for the 'primitive' members of Sticholotidinae and broadly defined Coccinellinae for the remaining taxa. Phylogenetic analysis to resolve the evolutionary relationships based on molecular and morphological data could not demonstrate any significant support on the division of Coccinellidae into six subfamilies including Scymninae. The coccinellids previously treated under the subfamily Scymninae were designated under the subfamily Coccinellinae. Of the tribes previously under Scymninae, Aspidimerini, Cryptognathini, Hyperaspini, Diomini, and Selvadiini maintained their tribe status and were grouped under the subfamily Coccinellinae whereas Scymnini, Scymnillini and Stethorini were treated as a part of the composite tribe Coccidulini and Brachiacanthini as a part of Hyperaspini under the subfamily Coccinellinae (Seago *et al.*, 2011).

Phylogenetic studies of different tribes of Scymninae by Kovar (1996) based on morphology lead to a conclusion that Stethorini might be the most primitive tribe under Scymninae. Sasaji (1968) opined that Stethorini might be regarded as a descendant from Scymnini-like ancestor in rather early geological age. Tribe Scymnini is reported as a main stock consisting of very rich genera and species in the family Scymninae. The tribes Aspidimerini showed high affinity to Scymnini especially to genus *Pseudoscymnus*. Some of the members of Ortaliini could be easily combined with Scymnini especially with the genus *Axinoscymnus*. Tribe Hyperaspini was also closely related to Scymninae. But these relationships were not generated by formal phylogenetic methods.

Molecular evidences revealed subfamily Scymninae to be paraphyletic (Robertson *et al.*, 2008; Giorgi *et al.*, 2009). Magro *et al.* (2010) studied the monophyly of different subfamilies of the Coccinellidae based on the molecular data of 61 species. Fifteen species under seven genera within four tribes under Scymninae were treated in the analysis. The study supported the polyphyly of Scymninae and among Scymninae, the tribe Scymnini was also polyphyletic. Among Scymninae, genus *Stethorus* occupied the basal position. The genera *Nephus, Scymnus* and *Diomus* were monophyletic in the subfamily Scymninae and *Nephus* and *Scymnus* were identified as sister taxa. Genus *Cryptolaemus* constituted a distinct lineage and genera *Cryptolaemus* and *Clitostethus* occupied an ambiguous position within the family, but never associated with the genera *Scymnus* and *Nephus*. The genera *Diomus* and *Hyperaspis* appeared to be closely related.

Phylogenetic studies by Seago *et al.* (2011), based on the morphological and molecular data representing seven proposed subfamilies and 42 tribes, included seven genera under the tribe Scymnini and one genus under the tribe Stethorini. The results showed that Scymnini formed a clade except for *Horniolus*, which formed a clade with *Rodolia* placed within the tribe Coccidulini under the broadly defined subfamily Coccinellinae.

2. 5. Tribe Scymnini Mulsant, 1846

Scymnini is one of the largest tribe in the family Coccinellidae and members of this group are predaceous on aphids, mealybugs, whiteflies, scales and adelgids (Kamiya, 1961; White, 1983). The tribe Scymnini was erected by Mulsant (1846) with type genus *Scymnus* Kugelann. He defined a group 'Scymniaires' (which was equivalent to "Scymnini, Pharini pars and Coccidulini pars" in *Coleopterorum Catalogus*, Coccinellidae by Korschefsky) within "Scymniens" in the division of hairy Coccinellidae (Trichosomides). The name Scymnini was given by Costa in 1849 (Vandenberg, 2002).

Weise (1879) referred Scymnini as one of the groups under 'Coccinellidae aphidiphagae', the major group within Coccinellidae. Ganglbauer (1899), in his study on European genera, classified Scymnini under the subfamily Coccinellinae. Scymnini was regarded as a tribe by Casey (1899) in his study on North American Coleoptera and as a group under Coccinellidae aphidiphagae by Sicard (1907, 1909) on Madagascan Coccinellidae. Korschefsky (1931 and 1932) arranged Scymnini, which comprised of 20 genera, within Coccinellinae. Members of tribe Stethorini were also included in the tribe Scymnini, even though Dobzhansky separated Stethorini from Scymnini in 1924.

When Sasaji (1968) defined Scymninae, the tribe Scymnini was accommodated in this subfamily. This classification was widely accepted and followed by many taxonomists (Gordon, 1976, 1985; Chazeau *et al.*, 1989; Kovar, 1996). Recently, Slipinski (2007) proposed a new classification based on the comprehensive study of Australian Coccinellidae and recognised two subfamilies under Coccinellidae. Seago *et al.* (2011) revised the classification of Coccinellidae and the tribe Scymnini is treated as a part of composite tribe Cocciduluni within the subfamily Coccinellinae.

2. 5. 1. Genera under the tribe Scymnini

Fursch (1990) listed the valid genera and subgenera of Coccinellidae (updated up to September 2007) and recognised 21 genera under the tribe Scymnini. The genera and subgenera designated are *Acoccidula* Barovsky, 1928; *Aponephus* Booth, 1991; *Apseudoscymnus* Hoang, 1984; *Axinoscymnus* Kamiya, 1963; *Clitostethus* Weise, 1885; *Cryptolaemus* Mulsant,1853; *Cyrema* Blackburn, 1889; *Didion* Casey, 1889; *Horniolus* Weise, 1900; *Keiscymnus* Sasaji,1971; *Leptoscymnus* Iablokoff-Khnzorian, 1978; *Midis* Mulsant, 1850; *Nephaspis* Casey, 1899; *Nephus* (*Bipuctatus*) Fursch, 1987; *N.* (*Depressoscymnus*) Gordon, 1976; *N.* (*Geminosipho*) Fursch, 1987; *N.* (*Nephus*) Mulsant, 1846; *N.* (*Parascymnus*) Chapin, 1965; *N.* (*Scymnobius*) Casey, 1899; *N.* (*Sidis*) Mulsant, 1850; *N.* (*Turboscymnus*) Gordon, 1976; *Parasidis* Brethes, 1924; *Propiptus* Weise, 1901; *Pseudoscymnus* Chapin, 1962; *Scymniscus* Dobzhansky, 1928; *Scymnodes*

(*Apolinus*) Pope and Lawrence, 1990; *S.* (*Scymnodes*) Blackburn, 1889; *Scymnus* (*Mimopullus*) Fursch, 1987; *S.* (*Neopullus*) Sasaji, 1971; *S.* (*Orthoscymnus*) Canepari, 1997; *S.* (*Parapullus*) Yang, 1978; *S.* (*Pullus*) Mulsant, 1846; *S.* (*Scymnus*) Kugelann, 1794; *Veronicobius* Broun, 1893. This was slightly modified by Nedved and Kovar (2012) by enlisting 18 genera under the tribe Scymnini. The modifications included separation of two genera, *Scymnodes* and *Cryptolaemus* from Scymnini and addition of a new genus *Pullosidis* Fursch, 1987 to Scymnini. *Nephaspis* and *Didion* which were earlier regarded as genera, were included within the genus *Clitostethus* and *Scymnus* respectively. Genus *Pseudoscymnus* was synonymized with *Sasajiscymnus* Vandenberg, 2004 (Vandenberg, 2004).

2. 5. 2. Major studies on Scymnini

The major taxonomic works on Scymnini in different geographical regions are presented below. Weise (1879, 1885) recorded seven species of *Scymnus* from Japan based on the collection of the Deutsches Entomologisches Institut. The revision of the tribe Scymnini from Japan and the Loochoos by Kamiya (1961), identified three genera *Clitostethus*, *Stethorus* and *Scymnus* with four subgenera, *Scymnus*; *Pullus*; *Nippopullus* and *Nephus*. Sasaji (1971) in his comprehensive studies on Coccinellidae of Japan, recognized 61 species under the tribe Scymnini, which were classified in seven genera *viz.*, *Cryptolaemus*, *Keiscymnus*, *Pseudoscymnus*, *Axinoscymnus*, *Horniolus, Nephus* and *Scymnus*. The subgenera identified under *Scymnus* include *S.* (*Scymnus*), *S.* (*Pullus*), *S.* (*Neopullus*) and *S.* (*Nipponpullus*).

Belicek (1976) studied the Coccinellidae of Western Canada and Alaska and identified 17 species of Scymnini belonging to three genera. He also revised generic classification of North American Coccinellidae for which he followed Sasaji's (1968) arrangement for suprageneric taxa and modified the arrangement of genera within the tribes from that used by Arnett (1968) and included seven genera under Scymnini: *Scymnus* (subgenera: *Scymnus*, *Pullus*), *Nephus* (subgenera: *Nephus*, *Sidis*, *Turboscymnus*, *Scymnobius*, *Depressoscymnus*), *Diomus*, *Cephaloscymnus*, *Selvadius*, *Didion*, *Blaisdelliana*. Gordon (1976, 1985) extensively studied on

North American Coccinellidae and identified six genera within Scymnini, which were *Nephaspis*, *Cryptolaemus*, *Diomus*, *Scymnus*, *Didion* and *Nephus*. Genus *Scymnus* was further divided into two subgenera *Scymnus* and *Pullus* and Genus *Nephus* into five subgenera *Nephus*, *Sidis*, *Turboscymnus*, *Scymnobius* and *Depressoscymnus*.

Other major taxonomic works that have been published which include the tribe Scymnini from different geographical regions were by Bielawski (1984) from Mongolia, Kuznetsov and Ren (1991) from Vietnam, Gordon (2000) from Neotropical region, Kovar (2007) from Palaearctic region, Slipinski *et al.* (2012) and Poorani *et al.* (2014) from Australia and Chen *et al.* (2012, 2013, 2014, 2015a, 2015b, 2015c, 2016a, 2016b) from China.

Many regional species lists of Scymnini that have been published include: species list of Arkansas by Rouse and Chapin (1976); Indian subregion by Poorani (2002); South Dakota by Hesler and Kieckhefer (2008); Iowa, USA by Hesler (2009); Iran by Jafari *et al.* (2015) and Mesbah *et al.* (2016).

Literature pertaining to the genera under Scymnini reported from Indian subregion is reviewed here.

2. 5. 2. 1. Genus *Axinoscymnus* Kamiya, 1963

The genus *Axinoscymnus* was erected by Kamiya (1963) with type species *Axinoscymnus beneficus* from Japan. Later, Kamiya (1965b) added two more species, *A. nigripennis* and *A. rai* from Japan and Kapur and Mushi (1965) added one species *A. puttarudriahi* from India.

2. 5. 2. 2. Genus *Clitostethus* Weise, 1885

Genus *Clitostethus* was described by Weise (1885) with *Clitostethus arcuatus* as type species. *Clitostethus* is a small genus with 18 described species. Poorani (2002) opined that two species of *Clitostethus* reported from Sri Lanka and Myanmar might belong to *Axinoscymnus* and *Pseudoscymnus*. But *Pseudoscymnus*

luteoniger Canepari reported from Nepal appeared to belong to the genus *Clitostethus* (Yu *et al.*, 2000).

2. 5. 2. 3. Genus *Cryptolaemus* Mulsant, 1853

Mulsant (1853a) described the genus *Cryptolaemus* with type genus *Cryptolaemus montrouzieri*. It is indigenous to the Australasian region with natural range extending from Sulawesi and Moluccan Indonesia to New Guinea and Australia (Booth and Pope, 1986; Slipinski, 2007). Forty species have been reported from Australian region (Poorani *et al.*, 2014). Booth and Pope (1986) reviewed this genus and identified two species groups: the *montrouzieri*-group and the *subviolaceus*-group. Poorani *et al.* (2014) extensively reviewed the genus *Cryptolaemus* endemic to New Guinea/ Australia and recognised thirty two new species and four new species groups: *iodes*- group, *magnificus*-group, *riedeli*-group and *bicolor*-group. *Cryptolaemus montrouzieri* is the most important species and was introduced to India, USA, UK and many other countries as a bicontrol agent against various mealybugs (NBAIR, 2013).

2. 5. 2. 4. Genus *Horniolus* Weise, 1900

The genus *Horniolus* was described by Weise (1900) with type species *Horniolus dispar* Weise. Only 15 species have been reported worldwide in this genus occurring from East to South and Southeast Asia. Miyatake (1963) transferred *Scymnus fortunatus* Lewis, 1896 to *Horniolus* and described nine species from Japan, China, India, Malaysia, Thailand and Vietnam (1976, 1979). Other taxonomists who described the species within *Horniolus* were Hoang (1979) from Vietnam and Poorani (2015a) from India. *Scymnus guimeti* Mulsant, 1850 was transferred to the genus *Horniolus* by Booth and Pope (1989).

2. 5. 2 .5. Genus *Nephus* Mulsant, 1846

Mulsant (1846) described *Nephus* as a subgenus of *Scymnus* with *Coccinella quadrilunulatus* Illiger, 1798 (=*Nephus quadrimaculatus* (Herbst, 1783)) as its type species. The name *Nephus* was derived from a Greek word '*nephos*' means cloud

(dark coloured) in reference to the body colour (Belicek, 1976). Later *Nephus* was raised to generic status. Kamiya (1961) and Bielawski (1984) also regarded *Nephus* as a subgenus of *Scymnus* in their study on Scymnini of Japan and Mongolia respectively. Gordon (1985), in the study on North American Coccinellidae arranged genus *Nephus* into five subgenera *viz.*, *Nephus* Mulsant 1846, *Sidis* Mulsant 1850, *Turboscymnus* Gordon, 1976, *Scymnobius* Casey, 1899 and *Depressoscymnus* Gordon 1976. Gordon recognized one species each under *N.* (*Nephus*), *N.* (*Sidis*), *N.* (*Turboscymnus*) and *N.* (*Depressoscymnus*) and 9 species under *N.* (*Scymnobius*). Other taxonomists who studied on *Nephus* include Kapur (1967) from Andamans, Sasaji (1971) from Japan and Golia and Golia (2014) from Florida.

2. 5. 2. 6. Genus *Sasajiscymnus* Vandenberg, 2004

Chapin (1962) proposed the genus *Pseudoscymnus* with *Scymnus hareja* Weise, 1879 as type species from Japan based on nine segmented antenna, extraordinary long setae on the terminal segment of antenna, three segmented tarsi and incomplete post coxal line. This was followed by the addition of five more species to this genus. *Pseudoscymnus* is a large genus with about 50 species mainly from East Asia and Africa (Yu *et al.*, 2000). Other major taxonomic works of *Pseudoscymnus* were by Sasaji (1971) from Japan (nine species), Canepari (1997) from Nepal (four species) and Yu *et al.* (2000) from China (five species).

Vandenberg (2002) suggested replacement of the genus name as *Pseudoscymnus* Chapin was preoccupied by *Pseudoscymnus* Herre 1935, which is a genus of kitefin shark. Vandenberg (2004) proposed *Sasajiscymnus* as an objective synonym for *Pseudoscymnus* Chapin. With this, all the species placed in *Pseudoscymnus* were transferred to genus *Saajiscymnus*.

2. 5. 2. 7. Genus *Scymnus* Kugelann, 1794

Scymnus is the largest and cosmopolitan genus, with more than 800 described species worldwide (Chen *et al.*, 2013). It is the second recognised genus in the family Coccinellidae and was described by Kugelann (1794), with *S.* (*S.*)

nigrinus as its type species, to accommodate small, hairy coccinellids that did not match with the first described genus *Coccinella* by Linnaeus (1758). The name *Scymnus* was derived from Greek, meaning 'lion's cub', in reference to resemblance of these pubescent beetles to little lions (Belicek, 1976).

Mulsant (1850) divided *Scymnus* into five subgenera, *Scymnus* Kugelann, 1794; *Pullus* Mulsant, 1846; *Nephus* Mulsant, 1846; *Diomus* Mulsant, 1850 and *Sidis* Mulsant, 1850 based on the shape of abdominal post coxal line. Bielawski (1984) followed this division of subgenera in his studies on Coccinellidae of Mongolia. Later, various changes have been observed in the arrangement of subgenera and among these, only two were retained within *Scymnus*, while other three had either their status changed or shifted to other tribe or genus. At present, eight subgenera identified under the genus *Scymnus* are *Scymnus* Kugelann, 1794 (=*Anisoscymnus* Crotch, 1874); *Pullus* Mulsant, 1846; *Didion* Casey, 1899 (=*Nipponopullus* Kamiya, 1961); *Neopullus* Sasaji, 1971 (=*Caledonus* Bielawski, 1973); *Parapullus*, 1978 (=*Paucus* Duverger, 1990); *Mimopullus* Fursch, 1987; *Orthoscymnus* Canepari, 1997 and *Canalipullus* Lafer, 2000 (Chen *et al.*, 2013). Many variations have been observed in the subgeneric classification of *Scymnus* from different geographical regions. Slipinski (2007) found that several Australian species of *Scymnus* could not be placed in the existing subgeneric classification and hence used in a very broad generic concept of *Scymnus*. Chen *et al.* (2013) reported that among eight subgenera of *Scymnus*, subgenera *Scymnus*, *Pullus*, *Neopullus* and *Parapullus* were distributed in China. *Scymnus*, *Pullus*, *Neopullus* and *Orthoscymnus* were the subgenera of *Scymnus* reported from Indian subregion (Poorani, 2002).

Subgenus *Scymnus* was described by Kugelann (1794) with *Scymnus nigrinus* as type species. Crotch (1874) rasied a new genus *Anisocymnus* with *Coccinella rufipes* Fabricius, 1798 as type species, which was later synonymized with subgenus *Scymnus*. The major distinguishable character that segregates *S.* (*Scymnus*) from its closely related subgenus *S.* (*Pullus*) is the presence of incomplete abdominal post coxal line, which is recurved forward basally, never

reaching the lateral margin of ventrite. The major taxonomic works on *S.* (*Scymnus*) from various geographical regions include studies by: Kamiya (1961) from Japan and the Loochoos (10 species), Sasaji (1971) from Japan (5 species), Belicek (1976) from Western Canada and Alaska (5 species), Bielawski (1984) from Mangolia (10 species), Gordon (1985) from North America (11 species), Canepari (1997) from the Nepal Himalayas (4 species), Yu *et al.* (2000) and Chen *et al.* (2013) from China (22 and 56 species).

Pullus was described by Mulsant (1846) with *Coccinella fasciata* Fourcroy, 1785 (= *Scymnus* (*Pullus*) *subvillosus* (Goeze, 1777)) as its type species and differentiated from *S.* (*Scymnus*) with the recurved and complete post coxal line. The name *Pullus* means 'a young bird in the downy stage', presumably in reference to small size and pubescent body (Belicek, 1976). *Pullus* is the largest subgenus of *Scymnus*, comprising of more than 500 species, among which 149 were described from the Palaearctic (Kovar, 2007), 154 from the Nearctic (Gordon, 1976, 1985), 27 from the Neotropical (Gordon, 2000), five from Australian (Slipinski *et al.*, 2012), 78 from Oriental (Hoang, 1982; Kuznetsov and Ren, 1991; Poorani, 2002) and 50 from the Afrotropical region (Fursch 1970, 1986, 1987, 1997; Chazeau and Couturier, 1985). The major taxonomic works on *S.* (*Pullus*) from various geographical regions include: Sasaji (1971) from Japan (21 species), Belicek (1976) from Western Canada and Alaska (7 species), Bielawski (1984) from Mangolia (4 species), Gordon (1985) from North America (79 species), Canepari (1997) from the Nepal Himalayas (17 species) and Chen *et al.* (2015a, 2015b) from China (260 species). Chen *et al.* (2015b) divided species recognized within *Pullus* into five species groups based on the characters of male genitalia and designated as *hingstoni*, *subvillosus*, *impexus*, *perdere* and *sodalis* groups.

Didion was first described as a genus of Scymnini by Casey (1899) with *Didion longulum* Casey as its type species. Members were similar to *S.* (*Pullus*), but differentiated with the 10-segmented antennae and absence of complete prosternal carinae (Gordon, 1985). Kamiya (1961) recognized a new subgenus *Nipponopullus* of *Scymnus* with *Scymnus* (*Nipponopullus*) *pirikamenoko* as its type

species. Sasaji (1971) described one species under subgenus *S.* (*Nipponopullus*) in his study on Japanese Coccinellids. Three species each of *Didion* were studied by Belicek (1976) and Gordon (1985) in their study on North American Coccinellids. Later subgenus *Nipponopullus* was synonymised with *Didion* and genus *Didion* was reduced to subgenus of *Scymnus.*

Sasaji (1971) established a new subgenus *Neopullus* of *Scymnus* with *Scymnus hoffmani* Weise, 1879 as the type species based on the presence of 10 segmented antenna with eight segmented flagellum, distinct prosternal carinae and complete abdominal post coxal line with uniformly punctate enclosed area. Another subgenus *Caledonus* of *Scymnus* was proposed by Bielawski (1973) with *S. angusticollis* Fauvel, 1903 as the type species. However, Yu and Pang (1992) synonymized *Caledonus* with *Neopullus*. Twenty nine species have been recognized in the world within the subgenus *Neopullus.* The major taxonomic studies on *Neopullus* were by Sasaji (1971) from Japan (seven species), Hoang (1982) from Vietnam (one species), Canepari (1986) from Nepal (one species), Fursch (1987) from Palaearctic region (four species), Yu *et al.* (2000) and Chen *et al.* (2014) from China (18 species).

The subgenus *Scymnus* (*Parapullus*) is a small subgenus of *Scymnus*, comprising of 20 species (Chen *et al.*, 2015c) and was erected by Yang (1978a), with type species *Scymnus* (*Parapullus*) *secula* Yang, 1978. The principal distinguishable characters of *Parapullus* are abdominal postcoxal lines distinctly incomplete laterally, antenna composed of ten antennomeres, parameres of the tegmen usually with two groups of long setae inserted in different directions. Major taxonomic works in this subgenus is from China (Yu *et al.*, 2000; Chen *et al.*, 2012; 2015c)

The subgenus *Orthoscymnus* of *Scymnus* was created by Canepari (1997) with *S.* (*Orthoscymnus*) *smetanai* Canepari, 1997 as the type species based on male genitalia that has sipho with large and irregular basal capsule and female genitalia with genital plates disposed sub horizontally. *Orthoscymnus* comprises of only

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seven species and are reported only from Nepal and China (Canepari, 1997; Chen *et al.*, 2016a).

Subgenus *Canalipullus* of *Scymnus* was erected by Lafer (2000) to accommodate a single species *Scymnus* (*Canalipullus*) *kunashirensis* from Kuril Islands. This subgenus is similar to *S.* (*Pullus*) except for the macrosculpture on pronotum.

Subgenus *Mimopullus* was proposed by Fursch (1987) with *S.* (*Pullus*) *medierraneus* Iablokoff-Khnzorian, 1969 as the type species.

2. 5. 2. 8. Genus *Diomus* Mulsant, 1850 (earlier)

Mulsant (1850) described the genus *Diomus* as a subgenus of *Scymnus* Kugelann. Status of this genus varied greatly and Gordon (1999) separated *Diomus* from Scymnini and erected a new tribe Diomini.

2. 5. 3. Studies on Scymnini from India

The pioneering work on Coccinellidae from India was by Subramanian (1923), who gave an account of *Scymnus xerampelinus* Mulsant feeding on *Phenococcus insolitus* Green in his list of 37 species of Coccinellids from South India. Ayyar (1925) described *Scymnus coccivora* Ayyar predaceous on the neem scale, *Chloropulvinaria maxima* (Green). Puttarudriah and Channabasavanna (1953, 1955, 1956) studied the Coccinellidae of Karnataka and recorded 53 species under 23 genera. Other major taxonomic treatments of Coccinellidae involving the tribe Scymnini were the studies of Chelliah (1965), who described the male genitalia of four species of coccinellids; Canepari (1986) who studied the type material of 36 species of Coccinellidae from Northern India and Nepal in the Geneva Museum and Booth (1991) who described a new genus *Aponephus*. The studies of Kapur was of great significance with regard to the taxonomy of coccinellids in India, of which the salient works were the records of the Indian Museum on Coccinellidae of Nepal (1958), the third Mount Everest Expedition, 1924 (1963), Coccinellidae of the Andamans (1967) and Goa (1972).

Poorani (2002) published an annotated checklist of the Coccinellidae (Coleoptera) (excluding Epilachninae) of the Indian sub-region, in which she listed 86 species of Scymnini under eight genera, of which 55 species were reported from India. In this, one species each of *Axinoscymnus* and *Cryptolaemus*, two species of *Horniolus*, five species of *Nephus*, four species of *Pseudoscymnus*, 42 species of *Scymnus* are reported from India.

The only species of *Axinoscymnus* reported from India is *A. puttarudriahi* Kapur and Munshi, 1965 feeding on whiteflies (Kapur and Munshi, 1965). This species was first described from India and present in all the south Indian states.

Cryptolaemus montrouzieri is the only species of *Cryptolaemus* present in India and was introduced as a natural enemy and released in 1898 in the Nilgiri Hills to check *Coccus viridis* and other mealybugs of coffee (Mayne, 1953). Later, it was rediscovered in 1951, though it had established much earlier (Puttarudriah *et al.*, 1952). It is the most common predator of mealybugs and soft scales infesting different horticultural, plantation and ornamental crops of south India (NBAIR, 2013).

The two species of *Horniolus* reported from India are from South India and include *H. nigripes* Miyatake, 1976 and *H. sororius*, 2015 Poorani. Mulsant (1850) described *Scymnus guimeti* and Booth and Pope (1989) revised it to *H. guimeti*. But he expressed his concern that Indian records of *H. guimeti* were mostly misidentifications of *Scymnus* (*Pullus*) *latemaculatus*. He also raised a doubt on whether undescribed species near to *H. vietnamicus* Miyatake occured in Karnataka, India (Poorani, 2002).

Indian species of *Nephus* include *N. bistillatus* (Mulsant), *N. lentiformis* (Booth), *N. regularis* (Sicard), *N. severini* (Weise) and *N. tagiapatus* (Kamiya). *Nephus lentiformis* was first described under the new genus *Aponephus* which was preying on *Rastrococcus* sp. from south India. However, *Aponephus* was synonymised with *Nephus* (Poorani, 2002). Kapur (1967) described a new species *N. roonwali* from Andamans and later synonymized with *N. tagiapatus* by Sasaji (1968).

Four species of *Pseudoscymnus* reported from India are *P. dwipakalpa* (Ghorpade), *P. luteus* (Sicard)!!, *P. pallidicollis* (Mulsant) and *P. simmondsi* Chapin and Ahmad, of which *P. dwipakalpa* were reported from Kerala, Karnataka and Tamil Nadu and *P. luteus* from Kerala (Poorani, 2002). Selvkumaran *et al.* (1996) studied natural enemies of two major species of scale insects infesting black pepper and reported *P. dwipakalpa* and other three species of *Pseudoscymnus*.

Among the 42 species of *Scymnus* listed (Poorani, 2002) from India, three were of subgenus *Neopullus*, 29 of *Pullus*, eight of *Scymnus* and one species belonged to an unknown subgenus. *Scymnus* (*Pullus*) *coccivora* Ayyar, *S.* (*P.*) *assamensis* Canepari, *S.* (*P.*) *bengalicus* Canepari, *S.* (*P.*) *besucheti* Canepari, S. (*P.*) *facetus* Canepari, *S.* (*P.*) *meghalayae* Canepari, *S.* (*P.*) *nymphaeus* (Kapur and Munshi) were first described from India. Other species of *Scymnus* recorded from India included *S.* (*S.*) *andrewesi* Sicard, *S.* (*S.*) *apiciflavus* (Motschulsky), *S.* (*S.*) *indicus* Weise, *S.* (*S.*) *lepidulus* Motschulsky, *S.* (*S.*) *levaillanti* (Mulsant), *S.* (*S.*) *nubilus* Mulsant, *S.* (*S.*) *tristigmaticus* Gorham, *S.* (*S.*) *venalis* Mulsant, *S.* (*P.*) *castaneus* Sicard, *S.* (*P.*) *ceylonicus* Motschulsky, *S.* (*P.*) *coccivora*, *S.* (*P.*) *giganteus* Kamiya, *S.* (*P.*) *harejoides* (Sicard), *S.* (*P.*) *hilaris* Motschulsky, *S.* (*P.*) *hingstoni* (Kapur), *S.* (*P.*) *impexus* (Mulsant), *S.* (*P.*) *kawamurai* (Ohta), *S.* (*P.*) *latemaculatus* Motschulsky, *S.* (*P.*) *nepalensis* Bielawski, *S.* (*P.*) *o-nigrum* Mulsant, *S.* (*P.*) *posticalis* Sicard, *S.* (*P.*) *pyrocheilus* Mulsant, *S.* (*P.*) *saciformis* Motschulsky, *S.* (*P.*) *sapporensis* (Ohta), *S.* (*P.*) *sodalis* (Weise), *S.* (*P.*) *testacecollis* (Kapur), *S.* (*P.*) *victoris* Crotch, *S.* (*P.*) *victoris unimaculata* Korschefsky, *S.* (*P.*) *uninotata* (Gorham), *S.* (*P.*) *xerampelinus* Mulsant, *S.* (*P.*) *zonatus* (Sicard), *S.* (*N.*) *fuscatus* Boheman, *S.* (*N.*) *hoffmanni* Weise, *S.* (*N.*) *loebli* Canepari and *S. seriatus* Weise.

The species recorded from south India include *S.* (*Neopullus*) *fuscatus* Boheman, 1859 from Karnataka, *S.* (*Pullus*) *castaneus* Sicard, 1929 from Karnataka (Puttarudriah & Channabasavanna 1953; Bhaskar, 1992; Mani and Krishnamoorthy, 1995; Megha *et al.*, 2015) and Tamil Nadu (Rekha *et al.* 2007); *S.* (*P.*) *ceylonicus* Motschulsky from Karnataka; *S.* (*P.*) *coccivora* from Kerala

(Jose, 2003), Karnataka (Puttarudriah & Channabasavanna 1953; Bhaskar, 1992; Megha *et al.*, 2015), Tamil Nadu (Karuppuchamy *et al.*, 1998; Rekha *et al.* 2007) and Anthra Pradesh (Padmaja *et al.*, 1995); *S.* (*P.*) *latemaculatus* Motschulsky from Kerala (Padmalatha and Singh, 1998; Jose, 2003), Karnataka and Tamil Nadu (Poorani, 2002); *S.* (*P.*) *uninotata* (Gorham) from Karnataka; *S.* (*P.*) *xerampelinus* from Karnataka (Puttarudriah & Channabasavanna 1953; Bhaskar, 1992) and Tamil Nadu; *S.* (*S.*) *andrewesi* Sicard from Karnataka; *S.* (*S.*) *indicus* Weise from Karnataka and *S.* (*S.*) *nubilus* Mulsant from Kerala (Jose, 2003), Karnataka and Tamil Nadu; *S.* (*P.*) *pyrocheilus* Mulsant (Padmalatha and Singh, 1998; Jose, 2003) from Kerala and *Pseudoscymnus luteus* (Sicard) from Kerala. Recently, Poorani (2015a) described a new species *S.* (*P.*) *rajeswariae*, which was highly host specific and found associated with Bamboo woolly aphid, *Pseudoregma bambusicola* (Takahashi).

2. 5. 4. Distribution of Scymnini in India

Based on available literature the distribution Scymnini in India is given (Table 2). The species collected during the present study is only included.

Table 2. Distribution of Scymnini in India

Species	Distribution within India	References
Axinoscymnus puttarudriahi	Hyderabad, Andhra Pradesh Kerala, Karnataka, Tamil Nadu and Lakshadweep Islands Shimoga, Karnataka Tamil Nadu	Mani *et al.*, 2001 Poorani, 2002 Aishwariya *et al.*, 2007 Sakthivel *et al.*, 2009
Cryptolaemus montrouzieri	Introduced to India	Mayne, 1953
Horniolus sororius	Tamil Nadu	Poorani, 2015a
Nephus regularis	Jabalpur, Madhya Pradesh Delhi	Rawat and Modi, 1969 Gautam *et al.*, 2007

	Madurai, Periyakulam Hisar, Haryana Andhra Pradesh, Assam, Karnataka Ludhiana and Amritsar, Punjab	Rekha *et al.*, 2007 Kedar *et al.*, 2011 NBAIR, 2013 Singh and Kaur, 2017
Nephus tagiapatus	Andamans	Kapur, 1967
Scymnus (Pullus) castaneus	Dharwad, Karnataka Bangalore, Karnataka Madurai, Periyakulam Chintamani, Karnataka Puri, Orissa Goa	Patnaik *et al.*, 1977 Bhaskar, 1992; Mani and Krishnamoorthy, 1995 Rekha *et al.*, 2007 Vidya and Ranjanna, 2014 Megha *et al.*, 2015 Maruthadurai and Singh, 2017
Scymnus (Pullus) coccivora	Bihar Jabalpur, Madhya Pradesh Uttar Pradesh Karnataka Salem, Tamil Nadu Namakkal, Tamil Nadu Kerala Delhi Madurai and Periyakulam Hisar, Haryana Dharwad, Karnataka	Ali, 1963 Rawat and Modi, 1969 Tandon and Srivastava, 1980 Mani *et al.*, 1987; Bhaskar, 1992 Pillai and Gopi, 1990 Karuppuchamy *et al.*, 1998 Jose, 2003 Gautam *et al.*, 2007 Rekha *et al.*, 2007 Kedar *et al.*, 2011 Megha *et al.*, 2015
Scymnus (Pullus) latemaculatus	Bangalore, Karnataka	Mani and Krishnamoorthy, 1995

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	Karyavattam, Kerala	Padmalatha and Singh, 1998
	Kerala	Jose, 2003
	Madurai, Tamil Nadu	Baskaran *et al.*, 2009
	Navasari, Gujarat	Jadhav and Shukla, 2015
Scymnnus (*Pullus*) *pyrocheilus*	Karyavattam, Kerala	Padmalatha and Singh, 1998
	Darjeeling, West Bengal	Konar, 1998
	Orissa	Basu and Patro, 2007
	Punjab	Singh *et al.*, 2016
Scymnus (*Pullus*) *rajeswariae*	Karnataka	Poorani, 2015a
Scymnus (*Scymnus*) *nubilus*	Orissa	Kapur, 1940
	Bihar	Ali, 1963
	Rajasthan	Saxena, 1971
	Haryana	Butani, 1971
	Vellayani, Kerala	Johnson, 1972
	Uttar Pradesh; Lucknow	Faruqui *et al.*, 1986; Omkar and Bind, 1995
	Bangalore, Karnataka	Bhaskar, 1992
	Kerala	Jose, 2003
	Perambalur, Tamil Nadu	Sankar *et al.*, 2011
	Dharwad, Karnataka	Megha *et al.*, 2015
	Punjab	Singh *et al.*, 2016

2. 6. Tribe Stethorini Dobzhansky

Tribe Stethorini is a cosmopolitan tribe and the only specialist mite predator in the family Coccinellidae, consisting of 90 species in two genera (Biddinger *et al.*, 2009). Dobzhansky (1924) erected the tribe Stethorini with type genus *Stethorus* Weise, to place a single genus *Stethorus* from the tribe Scymnini. This was based on the peculiar structure of the female genitalia of the species, *Stethorus*

punctillum, which has only two ovarioles and is devoid of bursa copulatrix, receptaculum seminis and accessory glands. This treatment had never been accepted by many coleopterologists. Korschefsky (1931 and 1932) synonymized Stethorini with Scymnini and arranged the genus *Stethorus* under Scymnini within the subfamily Coccinellinae. Sasaji (1968) classified Stethorini as a separate tribe under Scymninae and this was followed by many taxonomists (Gordon, 1985; Chazeau *et al.*, 1989; Kovar, 1996). Recently, the revision of subfamilies of Coccinellidae by Slipinski (2007) and Seago *et al.* (2011) treated Stethorini as a part of composite tribe Cocciduluni within the subfamily Coccinellinae.

2. 6. 1. Genera under the tribe Stethorini

The valid genera and subgenera of Coccinellidae by Fursch (1990) enlisted only one genus, *Stethorus* Weise (1885) under the tribe Stethorini. *Stethorus* was again subdivided into three subgenera *Allostethorus*, *Parastethorus* and *Stethorus*. List of genera in tribes and subfamilies of Coccinellidae by Nedved and Kovar (2012) included *Stethorus* and *Parastethorus* under the tribe Stethorini.

2. 6. 1. 1. Genus *Stethorus* Weise 1885

Stethorus was originally proposed by Weise (1885) as a subgenus of *Scymnus* with *Coccinella minima* Rossi (=*Stethorus punctillum* Weise) as type species. But later, Weise and Casey regarded *Stethorus* as a valid genus. However, in some later works, this had been considered as a subgenus of *Scymnus* (Kapur, 1948). The name '*Stethorus*' was derived from Greek, which means 'breast+margin' in reference to the shape of pronotum (Belicek, 1976). *Stethorus* is widely distributed with about 95 species of *Stethorus* having been reported from all over the world (Li *et al.*, 2013).

Iablokoff-Khnzorian (1972) established the subgenus *Allostethorus* of *Stethorus* with *S.* (*A.*) *amurensis* as the type species particularly based on the shape of male genitalia. Of the total species of *Stethorus* described, 38 belong to the subgenus *Allostethorus*. Another subgenus *Parastethorus* of *Stethorus* was erected by Pang and Mao (1975), but later promoted to genus level by Slipinski (2007). The

subgenus *Stethorus* can be distinguished from subgenus *Allostethorus* by slender penis and terminal strut shorter than penis guide. Subgenus *Allostethorus* has short penis, stout penis guide, and terminal strut longer than penis guide. The major taxonomic works on *Stethorus* were by Kapur (1948, 1950, 1961) from Old world (21 species), Sasaji (1971) from Japan (4 species), Houston (1980) from Australia (4 species), Gordon and Chapin (1983) from New world, Ren and Pang (1996) and Li *et al.* (2013) from China (34 species).

2. 6. 1. 2. Genus *Parastethorus* Pang and Mao, 1975

Pang and Mao (1975) erected *Parastethorus* as a subgenus of *Stethorus* with *Stethorus* (*Parastethorus*) *yunnanensis* as its type species based on male genitalia and incomplete post coxal lines. A total of 11 species of *Parastethorus* have been reported from the oriental region (Li *et al.*, 2015). Members of *Parastethorus* have parameres with many short, stout setae on the inner side (Li *et al.*, 2013). Accordingly, the following species were placed to the subgenus *Parastethorus*: *S. truncatus* Kapur from Malaysia, *S. gutierrezi* Chazeau from New Hebrides, *S. nigripes* Kapur and *S. histrio* Chazeau from Australia (Gordon and Chapin, 1983), *S. dichiapiculus* Xiao, *S. guangxiensis* Pang and Mao, *S. indira* Kapur, *S. malaicus* Xiao and *S. yunnanensis* Pang and Mao (Yu, 1996). Ren and Pang (1996) and Li *et al.* (2015) described five new species of *Parastethorus* from China. Later, Slipinski (2007) raised the subgenus *Parastethorus* to generic status.

2. 6. 2. Studies on Stethorini from India

The most salient studies on *Stethorus* from India were by Kapur (1948, 1950, 1961). He studied seven known species from New World and twenty from Old World in 1948. Of the species studied from Old World, twelve were described as new to science. The *Stethorus* species recognised from India in the study were *S. gilvifrons* (Mulsant); *S. parcepunctatus* Kapur; *S. pauperculus* (Weise); *S. rani* Kapur and *S. tetranychi* Kapur. Later, he described two more species from India, *S. indira* Kapur (1950) and *S. keralicus* Kapur (1961). Pang and Mao (1975) described another species *S. guangxiensis* Pang and Mao and Poorani (2004)

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identified that *S. guangxiensis* was a junior synonym of *S. indira.* Later, Babu (2012) reported *S. aptus* (Kapur) in the tea growing areas of North East region. Very recently, Poorani (2017) described a new species, *S. forficatus* from South India.

The species of *Stethorus* recorded from South India include *S. gilvifrons* from Kerala and Karnataka; *S. guangxiensis* from Karnataka (Poorani, 2002); *S. keralicus* from Kerala (Kapur, 1961), Karnataka and Tamil Nadu (Poorani, 2002); *S. parcepunctatus* from Karnataka (Kapur, 1948); *S. pauperculus* from Kerala (Lenin and Bhaskar, 2016), Karnataka and Tamil Nadu (Poorani, 2002); *S. tetranychi* and *S. forficatus* from Tamil Nadu (Poorani, 2017).

2. 6. 3. Distribution of Stethorini in India

The distribution Indian Stethorini, based on literature is given below (Table 3). The species collected during the present study is only included.

Table 3. Distribution of Stethorini in India

Species	**Distribution within India**	**References**
Parastethorus indira	Calcutta	Kapur, 1950
Stethorus aptus	North eastern region	Babu, 2012
Stethorus forficatus	Thayanur, Tamil Nadu	Poorani, 2017
Stethorus keralicus	Kerala, Karnataka	Kapur, 1961; Puttaswamy and Rangaswamy, 1976
Stethorus parcepunctatus	Kanara	Kapur, 1948

Stethorus pauperculus	Coimbatore, Bangalore, Nadiad, Poona, Pusa, Delhi, Lyallpur	Kapur, 1948
	Jabalpur, Madhya Pradesh	Rawat and Modi, 1969
	Shimoga, Karnataka	Rachana *et al.*, 2009
	Bihar	Sambath, 2010
	Coimbatore, Tamil Nadu	Jeyarani *et al.*, 2012
	Navasari, Gujarat	Godhani and Shukla, 2015
	Kerala	Lenin and Bhaskar, 2016
Stethorus rani	Kumaon Hills	Kapur, 1948
Stethorus tetranychi	Thayanur, Tamil Nadu	Poorani, 2017

2. 7. Prey range of predaceous coccineliids

Family Coccinellidae exhibits a wide range of preferred food types spanning kingdoms and trophic levels. The evolution of Coccinellidae includes feeding transitions that cross kingdoms of life (plant, animal and fungus) and trophic levels (Giorgi *et al.*, 2009). The three major feeding habits recognized for coccinellids are zoophagy (predation), phytophagy (plant feeding) and mycophagy (fungus feeding). The preferred prey of predaceous coccinellids belong to the hemipteran suborder Sternorrhyncha which includes aphids, adelgids, scales, mealybugs, whiteflies, psyllids and also mites (Hodek and Honek, 2009; Obrycki *et al.*, 2009, Biddinger *et al.*, 2009). They also prey on young larvae of Lepidoptera, Coleoptera, Hymenoptera, nematoceran Diptera and Thysanoptera (Hodek, 1973).

2. 7. 1. Prey range of Scymnini

Members of the tribe Scymnini are predaceous on aphids, mealybugs, scales, whiteflies and adelgids. Aphids are the primary food source for most of the species of genus *Scymnus* (Gordon, 1976). Wheeler and Jubb (1979) observed *S. cervicalis* Mulsant preying on grape phylloxera in Pennsylvania, USA, which is an instance of essential prey food in the family Phylloxeridae.

Schilder and Schilder (1928) gave a detailed account of the prey range of coccinellids. A comprehensive list of prey of predaceous coccinellids of Japan was given by Kamiya (1966) and Sasaji (1967). Puttarudriah and Channabasavanna (1953, 1955, 1956) recorded several predatory coccinellids from Karnataka feeding on coccids, aphids, mealybugs and mites. Agarwala and Ghosh (1988) published the prey records of 36 aphidophagous Coccinellidae in India, in which they referred the prey range of nine species of *Scymnus*. Later, 45 aphidophagous coccinellids were reported from Northeastern states of India (Shantibala and Singh, 1991).

Omkar and Pervez (2004) published prey-predator catalogue for predaceous coccinellids in India which comprised of the prey range of 261 species belonging to 57 genera. The prey records of Scymnini as reviewed by Omkar and Pervez (2004) is furnished below (Table 4).

Table 4. Prey range of Scymnini from India

Coccinellids	**Prey**
Axinoscymnus puttarudriahi Kapur & Munshi	*Aleurodicus dispersus*
Cryptolaemus montrouzieri Mulsant	*Pulvinaria psidii*, *Pulvinaria* sp. *Pseudococcus* sp., *Eriococcus araucariae*, *Planococcus maxima*, *Planococcus insolitus*, *Psuedococcus* sp., *Planococcus citri*, *Maconellicoccus hirsutus*, *Planococcus lilacinus*, *Chloropulvinaria polygonata*, *Saccharicoccus sacchari*, *Aleurodicus dispersus*
Horniolus guimeti (Mulsant)	*Aphis gossypii*, *Aphis citricola*, *Aphis nerii*
Horniolus nigripes Miyatake	undet. Aphids
Nephus bistillatus (Mulsant)	*Ferrisia virgata*

Nephus lentiformis (Booth)	*Rastrococcus* sp.
Nephus quadrimaculatus (Herbst)	*Pseudococcus* sp.
Nephus regularis (Sicard)	*Centrococcus insolitus*, *Ferrisia virgata*, *Phenacoccus pacificus*, *Maconellicoccus hirsutus*, *Aphis gossypii*, *Chloropulvinaria polygonata*, *Rhopalosiphum maidis*, *Brevicoryne brassicae*, *Lipaphis erysimi*
Nephus severini (Weise)	*Planococcus lilacinus*
Nephus tagiapatus (Kamiya)	*Tetranychus* sp.
Pseudoscymnus dwipakalpa Ghorpade	*Aspidiotus destructor*, *Ceroplastes actiniformis*, *Vinsonia stellifera*, *Coccus acutissimus*, *Coccus hesperidum*, *Pseudaulacaspis* sp., *Palmicultor* sp., *Pseudococcus citriculus*
Pseudoscymnus luteus (Sicard)	*Pentalonia nigronervosa*
Pseudoscymnus pallidicollis (Mulsant)	*Aleurocanthus spiniferus*, *Ferrisia virgate*
Pseudoscymnus Simmondsi Chapin and Ahmad	scale-insects *Unaspis yanonensis*
Scymnus apiciflavus (Motschulsky)	*Aphis gossypii*
Scymnus andrewesi Sicard	*Pseudococcus saccharifolii*
Scymnus assamensis Canepari	undet. Aphids
Scymnus bengalicus Canepari	undet. Aphids
Scymnus besucheti Canepari	undet. Aphids

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Scymnus bourdilloni (Kapur)	undet. Aphids
Scymnus castaneus Sicard	*Aphis nerii, Rhopalosiphum maidis* *Aphis punicae, Aphis gossypii*
Scymnus ceylonicus Motschulsky	*Aphis gossypii*
Scymnus coccivora Ayyar	*Pseudococcus* sp., *Icerya aegyptiaca,* *Rastrococcus spinosus,* *Tetranychus ludeni, Psuedococcus* sp., *Ferrisia virgata, Maconellicoccus hirsutus* *Planococcus* sp., *Aphis punicae, Rastrococcus iceryoides*
Scymnus facetus Canepari	undet. aphids
Scymnus fuscatus Boheman	*Greenidea heeri,* *Rhopalosiphum nymphaeae*
Scymnus giganteus Kamiya	*Aphis gossypii, Tuberculatus indicus*
Scymnus gracilis Motschulsky	*Aleurolobus barodensis, Paratetranychus indicus, Eutetranychus orientalis,* *Oligonychus indicus, Hyalopterus arundinis,* *Aphis pomi, Myzus persicae*
Scymnus harejoides (Sicard)	*Tetranychus telarius*
Scymnus hilaris Motschulsky	*Aphis gossypii, Greenidea heeri*
Scymnus hingstoni (Kapur)	Aphids
Scymnus impexus (Mulsant)	undet.aphids
Scymnus indicus (Weise)	*Ferrisia virgate*
Scymnus kawamurai (Ohta)	*Aphis gossypii*
Scymnus latemaculatus Motschulsky	*Aphis punicae* *Aphis craccivora*
Scymnus levaillanti Mulsant	*Planococcus citri, Aphis gossypii*
Scymnus loebli Canepari	*Tetranychus* sp.

Scymnus Meghalayae Canepari	undet. Aphids
Scymnus nubilus Mulsant	*Aleurolobus barodensis*, *Aphis gossypii, Aphis craccivora*, *Ferrisia virgata*, *Pentalonia nigronervosa, Toxoptera odinae*, *Aphis nerii, Uroleucon compositae, Maconellicoccus hirsutus*
Scymnus nymphaeus (Kapur& Munshi)	*Rhopalosiphum nymphaeae*
Scymnus o-nigrum Mulsant	undet. Thrips, *Toxoptera citricida, Aphis spiraecola*
Scymnus picescens Gorham	*Rhopalosiphum nymphaeae*
Scymnus posticalis Sicard	*Toxoptera odinae*, *Aphis gossypii*
Scymnus pyrocheilus Mulsant	*Aphis gossypii*, *Myzus persicae, Aphis citricola*, *Aphis craccivora*, *C. formasartemisiae*, *Lipaphis erysimi*, *Macrosiphoniella sanborni*, *Macrosiphum rosaeiformis*, *Pentalonia nigronervosa*
Scymnus quadrillum Motschulsky	*A. laburni*, *Aphis gossypii*, *Rhopalosiphum maidis*, *Aphis nerii*, *Myzus persicae*, *Aonidiella aurantii*, *A. orientalis, Aphis craccivora*, *Aphis gossypii*, *A. nerii, Aphis rumicis*, *A.gossypii, Pentalonia nigronervosa*
Scymnus sapporensis (Ohta)	undet. Aphids
Scymnus sodalis (Weise)	*Metatetranychus ulmi*
Scymnus testacecollis (Kapur)	undet. Aphids

Scymnus tristigmaticus Gorham	*Oligonychus coffeae*
Scymnus venalis Mulsant	*Oligonychus coffeae*
Scymnus victoris Crotch	*Aphis nerii*
Scymnus uninotata (Gorham)	*Aphis gossypii*
Scymnus xerampelinus Mulsant	*Phenococcus insolitus*, *Aphis gossypii*, *Aphis craccivora, Bemisia tabaci*, *Aspidiotus destructor, Aphis nerii*, *Brevicoryne brassicae*, *Lipaphis erysimi*, *Macrosiphum graminis*
Scymnus zonatus (Sicard)	*Pseudoregma bucktoni*

(Source: Omkar and Pervez, 2004)

Apart from this, *Cryptolaemus montrouzieri* was reported to feed on *Paracoccus marginatus* (Regupathy and Ayyasamy, 2011); *Horniolus sororius* on coffee mealybug and *Aleurodicus dispersus* (Poorani, 2015a); *Nephus regularis* on *Nipaecoccus viridian* (Newstead) (Singh and Kaur, 2017), *Phenacoccus solani* (Gautam *et al.*, 2007) and *Paracoccus marginatus* (Regupathy and Ayyasamy, 2011); *Scymnus coccivora* on *Phenacoccus solenopsis* (Kedar *et al.*, 2011), *Phenacoccus solani* (Gautam *et al.*, 2007), *Paracoccus marginatus* (Regupathy and Ayyasamy, 2011) and *Pseudococcus saccharifolii* (Green) (Ali, 1963); *Scymnus nubilus* on *Phenacoccus solenopsis* (Sankar *et al.*, 2011) and *Pseudococcus saccharifolii* (Ali, 1963).

2. 7. 2. Prey range of Stethorini

Members of tribe Stethorini are unique among the Coccinellidae as they are the specialist mite predators. Adults as well as larvae are highly specialised predators of mites belonging to Tetranychidae (spider mites) and the closely related Tenuipalpidae (false spider mites or flat mites). Of the 68 known species, 40 per cent had been reported to attack spider mites of economic importance (Chazeau, 1985). Most species of *Stethorus* attack a large number of tetranychid mites, but some species are more selective in their choice. *Stethorus punctilllum*, *S. punctum*

and *S. gilvifrons* do not readily feed or oviposit on the genus *Bryobia* (Putman, 1955). Usually adults and larvae of Stethorini prefer mite eggs over other stages (Houck, 1991; Tanigoshi and McMurtry, 1977), but *S. madecassus* preferred adults over eggs as prey (Chazeau, 1974).

Stethorini are present throughout the world in different climates ranging from tropical rainforests to temperate deciduous forests and plains to colder northern region of Europe, Russia and Canada (Biddinger *et al.*, 2009). Chazeau (1985) and Biddinger *et al.* (2009) published the worldwide species of *Stethorus* preying on tetranychid and tenuipalpid mites on various hosts along with the region of their occurrence.

Omkar and Pervez (2004) published prey-predator catalogue for predaceous coccinellids in India and presented the prey records of seven species of Stethorini from India. The prey records of Stethorini as reviewed by Omkar and Pervez (2004) is furnished below (Table 5).

Table 5. Prey range of Stethorini from India

Coccinellids	**Prey**
Stethorus gilvifrons (Mulsant)	mites and thrips *Tetranychus aurantii*,red spider mites
Stethorus guangxiensis Pang & Mao	*Tetraychus telarius, Tetranychus cinnabarinus*, *Planococcus citri*
Stethorus indira Kapur	*Tetranychus* sp.
Stethorus keralicus Kapur	*Raoiella indica*
Stethorus parcepunctatus Kapur	*Tetranychus cinnabarinus*
Stethorus pauperculus (Weise)	*Oligonychus indicus, Raoiella indica, Tetranychus neocaledonicus, Eutetranychus orientalis, Tetranychus ludeni*
Stethorus rani Kapur	*Tetranychus cinnabarinus*

(Source: Omkar and Pervez, 2004)

In addition to the above, *S. aptus* preying upon *Oligonychus coffeae* Nietner (Babu, 2012), *S. pauperculus* on *Tetranychus truncatus* Ehara (Lenin and Bhaskar,

2016) and *S. forficatus* and *S. tetranychi* on citrus hindu mite, *Schizotetranychus hindustanicus* (Hirst) (Poorani, 2017) were also reported

2. 8. DNA barcoding for species identification

Genomic approaches to taxon diagnosis utilise diversity among DNA sequences to identify the organisms (Kurtzman, 1994; Wilson, 1995) and these sequences can be regarded as 'genetic barcodes'. Genetic barcode is any standardized subset of DNA from a taxonomic specimen. Although the genomic barcodes have only four alternate nucleotides at each position, the huge string of sites available for inspection creates a large number of possible combination of codes to discriminate life uniquely. Hebert *et al.* (2003) tried to exploit the prospect for a sustainable identification by a system that employ DNA sequences as taxon 'barcodes' and proposed that a part of the mitochondrial gene, cytochrome *c* oxidase subunit 1 (*COI* or cox1) can serve as the core of global identification system for animals. They established that the diversity in amino acid sequences coded by the 5'section of *COI* was sufficient to reliably place species into higher taxonomic categories (from phyla to orders). Mitochondrial cytochrome *c* oxidase subunit I shows variations at a frequency that allows clustering of individuals from same species and provides increasing distinction from more distinctly related vouchers. Molecular data can provide clues to possible species segregates and allow reinterpretation of existing morphological data (Gullan and Cranston, 2014).

DNA barcoding is a molecular diagnostic tool for species level identification and can be considered as an appropriate use of new technology to solve the problem of identifying and classifying the world's biodiversity (Will and Rubinoff, 2004). Due to the speed at which the *COI* sequence data can be generated and analysed, DNA barcoding represents a powerful tool for biodiversity assessment, quickly sorting collections into species-like units. DNA barcoding has two distinct aims: specimen identification and specimen discovery (Schindel and Miller, 2005). Specimen identification indicates assigning taxonomic names to unknown specimens with the help of a DNA reference library of morphologically preidentified vouchers. This is important for the identification of invasive species,

which may later become a threat to biodiversity (Collins *et al.*, 2012). Species discovery with DNA barcode is best thought of as a quick molecular parataxonomy process analogous to physically sorting specimens to morphospecies (Brower, 2006).

Hebert *et al.* (2013) studied on *COI* divergences among more than 13000 congeneric pairs under 11 phyla. They established that congeneric species of animals possess substantial sequences divergence in their *COI* genes and 79 per cent of species pairs showed greater than 8 per cent sequence divergence and more than 98 per cent of species pairs showed greater than 2 per cent sequence divergence. These results supported that species level diagnoses could be obtained through *COI* analysis. DNA barcoding supported the existence of cryptic species in the neotropical skipper butterfly (Lepidoptera: Hesperiidae) complex, which have subtle difference in adult morphology with no genitalic divergence, but caterpillars differ in colour pattern, food plants and ecosystem preferences. This study showed that *Astraptes fulgerator* is a complex of at least 10 species in Northwestern Costa Rica (Hebert *et al.*, 2004a).

Smith *et al.*, (2006) demonstrated that DNA barcoding could facilitate species discovery and identification of 20 morphospecies of *Belvosia*, parasitoid flies (Diptera: Tachinidae) of lepidopteran larvae in Northwestern Costa Rica. Hajibabaei *et al.* (2006) showed that DNA barcodes generated utilizing cytochrome *c* oxidase I effectively discriminated among species in three Lepidoptera families from Northwestern Costa Rica. They utilized *COI* sequences from 4260 adults that represented 521 morphologically defined species of family Hesperiidae, Sphingidae and Saturniidae. Of these, 97.9 per cent of the barcode sequences were unambiguously distinguishable from other species.

Species identification using DNA barcodes is reliable only if a significant difference between the average intra- and interspecific genetic distance can be consistently detected (Hebert *et al.*, 2004b, 2013; Barrett and Hebert, 2005). Such "Barcoding gap" is the existence of at least 10 times greater average interspecific distances over the average intraspecific genetic distance (Hebert *et al.*, 2004b).

Wiemers and Fiedler (2007) opined that the success of DNA barcoding depends either on the strength of the claim that interspecific variation exceeds intraspecific variation by one order of magnitude, which establishes "barcoding gap" or on the reciprocal monophyly of species. DNA barcoding in blue butterflies (Lepidoptera: Lycaenidae) found that the average divergence in 1189 intraspecific comparisons was 1.02 per cent and that in 236348 inerspecific comparisons was 9.38 per cent ranging from 0 to 23.2 per cent. The analysis showed that there was an 18 per cent overlap in the range of intra- and interspecific *COI* sequence divergence which may be due to low interspecific divergence between closely related species. They concluded that although DNA barcode helps to identify species, it was advocated to use them in combination with other data otherwise there would be a probability that sequences are misidentified. Size of the barcoding gap depends on taxonomic groups and hence it is necessary to establish a statistically better defined barcoding gap and its variation over taxonomic scales (Candek and Kuntner, 2014).

There are many international barcoding activities for the development of targeted public reference. Insect specific online resources were developed where DNA barcode can be submitted and retrieved for phylogenetic analysis and this include Lepidoptera: http://lepbarcoding.org/, Bee-BOL: http://www.bee-bol.org/, Trichoptera BOL:http://www.trichopterabol.org/, FormicidaeBOL: http://www.formicidaebol.org/, Mosquitos of the world http://www.lepbarcoding.org (Ojha *et al.*, 2014b).

A comprehensive study by Hendrich *et al.*, (2015) provided the globally largest DNA barcode reference library for Coleoptera belonging to 3514 well identified species with representatives of 97 families. Accordingly, 53 per cent of beetle fauna known from Germany were available in reference library on BOLD. Halim *et al.* (2017) generated DNA barcode for eight ladybug species (Coccinellidae) *viz.*, *Henosepilachna vigintioctopunctata*, *H. kaszabi*, *Micraspis discolor*, *Heteroneda reticulata*, *Chilocorus nigritus*, *Cheilomenes sexmaculata*, *Coelophoraina equalis* and *Coccinella transversalis* from Malaysia.

In India, out of the total known insect species of 58977, barcodes were generated for 3694 species belonging to 13 orders which include mainly Coleoptera (114), Diptera (650), Ephemeroptera (84), Hemiptera (710), Hymenoptera (167), Lepidoptera (1608) and Odonata (32). The coccinellid species for which DNA barcode generated from NBAIR include *Coccinella transversalis*, *Harmonia axyridis*, *Chilocorus nigrita*, *Cheilomenes sexmaculata*, *Cryptolaemus montrouzieri*, *Brumoides suturalis*, *Curinus coeruleus*, *Coccinella septempunctata*, *Hyperaspis maindroni*, *Rodolia amabilis*, *Scymnus latemaculatus* and *Henosepilachna vigintioctopunctata* (NBAIR, 2016).

The major barcoding works in India include barcoding of public health important mosquito species recorded in rural areas of south India (Paramasivan *et al.*, 2013), elucidation of cryptic diversity in thrips (Rebijith *et al.*, 2014) and aphids (Rebijith *et al.*, 2013), Indian ants (Ojha *et al.*, 2014a), host associated genetic diversity of tea mosquito bug (Chandrashekara *et al.*, 2015), molecular identification of mango hoppers in Punjab (Jindal *et al.*, 2016), diversity of Asian citrus psyllids (Chaitanya *et al.*, 2016) and DNA barcoding of *Helicoverpa armigera* (Ranjith and Chellappan, 2015).

Collins and Cruickshank (2012) provided an assessment of seven deficiencies of DNA barcoding and some potential improvements for its adaptation and adoption for more reliable and accuarate outcomes.

2. 8. 2. Phylogenetic analysis

DNA sequence analysis is enormously useful in studies of evolutionary history. A variety of genes and methods of analysis had been employed in DNA based phylogenetic research among which mitochondrial based markers had been used increasingly. Mitochondrial DNA possess strict maternal transmission (San *et al.*, 2006) with high mutation rate due to limited repair system (Brown *et al.*, 1979) and conserved simple structure. Mitochondrial ribosomal RNA, 12S r RNA, 16S r RNA, protein coding genes and mitochondrial noncoding region are the various

mtDNA markers that have been applied to the study of different species of insects (De Mandal *et al.*, 2014).

Zardoya and Meyer (1996) studied on mitochondrial protein coding genes, and found that *COI* was the best molecular marker for evolutionary studies. The mitochondrial gene encoding *COI* possess some characteristics with which it is particularly suitable as a molecular marker in phylogenetic studies. *COI* gene is the largest of the three mitochondria encoded cytochrome oxidase subunits and one the largest protein coding gene in the metazoan mitochondrial genome (Lunt *et al.*, 1996).

Hebert *et al.* (2003) proposed cytochrome *c* oxidase I gene as genetic barcode mainly because of two reasons; the universal primers for *COI* are very robust which enables the recovery of its 5' end from representatives of most animal phyla (Folmer *et al.*, 1994; Zhang and Hewitt, 1997) and *COI* appears to possess a greater range of phylogenetic signal than any other mitochondrial gene. The evolution of this gene is rapid to allow the discrimination of not only closely allied species but phylogeographic groups within a single species also (Cox and Hebert, 2001; Wares and Cunningham, 2001).

The molecular studies that have been reported on Coccinellidae are very few compared to other groups in the world (Aruggoda *et al.*, 2010). Cytochrome oxidase I (*COI*) gene of Epilachninae was investigated by Kobayashi *et al.* (1998) by studying the relationships among different species focusing on host shifts. Fu and Zhand (2006) studied on molecular systematic analysis of the family Coccinellidae by sequencing partial *COI* gene region to infer higher taxonomic level relationships of sixteen species of four subfamilies which could produce interesting outcomes regarding the relationships among species.

Cytochrome oxidase subunit I gene was one among five genes studied by Magro *et al.* (2010) to find out the phylogenetic relationships of different subfamilies of family Coccinelldiae. *COI* was exploited for the studies on phylogeny and classification of lady beetles (Seago *et al.*, 2011) and Cucujoidea

(Robertson *et al.*, 2015) and also on food plasticity in the evolution of true ladybird beetles (Escalona *et al.*, 2017).

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Material and methods

3. MATERIAL AND METHODS

The present study was undertaken in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 2014-17 to explore the diversity of Scymnini and Stethorini in different agricultural ecosystems of south Indian states of Kerala, Karnataka and Tamil Nadu.

The methods and techniques employed for the study are given below.

3. 1. Taxonomy

Taxonomic studies include collection of specimens and morphological characterization for the identification of species.

3. 1. 1. Source of specimens

3. 1. 1. 1. Collection and preservation of beetles and prey

3. 1. 1. 1. 1. Survey

Field surveys were carried out in different locations of Kerala, Karnataka and Tamil Nadu covering various agricultural ecosystems. The locations from where the collections were made along with the crops are given in Table 6 and Fig. 1. The GPS coordinates of the geographical locations are given in Appendix I.

3. 1. 1. 1. 2. Field collection

The methods described by Poorani (2012) was followed for collecting, preserving and processing of beetle specimens. The collection of beetles was carried out by using aspirators, beating and sweeping. Being predators of mealybugs, aphids, whiteflies, scales and mites, plants infested by these were focused. Both adults and immature stages associated with the prey were collected and the immature stages were reared in the laboratory till adult emergence. The main method adopted for collection of adults was aspiration. The branches of the trees with infestation were also beaten with stick and the fallen beetles were collected using a tray or umbrella kept underneath and transferred to the aspirator. Sweeping of vegetation was also done. The prey associated with the beetles were also collected to study the prey range.

Table 6. Locations and plants surveyed during the study

State	District	Locations	Plants surveyed
Kerala	Kasargod	COA, Padannakkad	Chilli, coconut, guava, tapioca
	Kannur	PRS, Panniyur	Banana, chilli, *Gliricidia*, pepper
	Wayanad	Banasura Sagar, Kariampady, Pulpally, RARS, Ambalavayal	Banana, coffee, *Erythrina*, *Gliricidia*, guava, jack, pepper
	Kozhikode	Mukkam	Arecanut, banana
	Malappuram	KVK, Tavanur	Brinjal, chilli, *Cosmos*, guava, *Hibiscus*, tapioca
	Palakkad	Vadakarapathy, Vadakkenchery, Vandazhy	*Annona*, arecanut, banana, chilli, cowpea, *Eupatorium*, *Gliricidia*, guava, star gooseberry
	Thrissur	Avinissery, Chalakkudy, Chazhur, Chembukkavu, Cherpu, Chirakkakkode, Elavally, Kodannur, Kottepadam, Mannuthy, Marakkal, Moorkkinikkara,	*Aerva lanata*, *Amaranthus*, *Annona*, arecanut, banana, bhindi, bottle palm, brinjal, *Butea monosperma*, *Celosia*, chilli, coconut, *Colocasia*, cowpea, *Croton*, *Eupatorium*, evergreen, *Gliricidia*, guava, *Hibiscus*, Indian gooseberry, jack, *Lantana*, long pepper, lotus, *Macaranga peltata*, maize, *Mikania*, *Mussaenda*,

		Olarikkara, Ollur, Parakkad, Pattikkad, Payyanam, Vellanikkara	*Mucuna*, mulberry, papaya, pineapple, *Plumeria*, red ginger, star gooseberry, tapioca, tulsi, *Zinnia*
	Ernakulam	Pineapple Research Station, Vazhakulam Perumbavoor	*Mikania*, pineapple, tapioca
	Kottayam	RARS, Kumarakom	Banana, chilli, *Colocasia*, *Gliricidia*, *Hibiscus*, *Mussaenda*, tapioca
	Alappuzha	RARS (Onattukara region), Kayamkulam	Arecanut, banana, coconut, *Gliricidia*, tapioca
	Idukki	CRS, Pampadumpara	Cardamom, *Dahlia*, *Hibiscus*
	Thiruvananthapuram	COA, Vellayani CTCRI, Sreekaryam	*Amaranthus*, banana, arecanut, *Colocasia*, cowpea, *Gliricidia*, jack, tapioca
Karnataka	Raichur	UAS campus, Raichur	*Abutilon*, bajra, bhindi, *Croton*, guava, maize, sorghum
	Dharwad	UAS campus, Dharwad	Cotton, *Croton*, guava, *Gliricidia*, *Hibiscus*, maize
	Shivamogga	UAHS campus, Shivamogga	Arecanut, banana, brinjal, cocoa, *Croton*, *Eupatorium*, *Gliricidia*, green gram, guava

	Bengaluru	UAS campus, Bengaluru	*Casuarina*, *Croton, Duranta*, *Gliricidia*, grapes, *Hibiscus*, jack, *Jatropha*
Tamil Nadu	Tiruchirappalli	HC & RI for women campus, Tiruchirappalli	*Abutilon*, *Achyranthes aspera*, coconut, *Desmodium* sp., guava, *Hibiscus*, , mango
	Tiruppur	Madathukulam	Castor
	Coimbatore	TNAU campus, Coimbatore	Papaya, *Jatropha*, *Hibiscus*, maize, tapioca
	Dindigul	HRS, Kodaikanal	Apple, peach, pear
	Madurai	AC & RI campus, Madurai, T. Kallupatti,	Banana, bhindi, brinjal, cotton, guava, mulberry, papaya, tamarind
	Theni	HC & RI , Periyakulam	Guava, sapota

AC & RI- Agricultural College and Research Institute; COA- College of Agriculture; CRS, Cardamom Research Station; CTCRI- Central Tuber Crops Research Institute; HC & RI- Horticulture College and Research Institute; HRS, Horticultural Research Station; KVK, Krishi Vigyan Kendra; PRS- Pepper Research Station, RARS- Regional Agricultural Research Station; TNAU- Tamil Nadu Agricultural University; UAHS- University of Agricultural and Horticultural Sciences; UAS-University of Agricultural Sciences

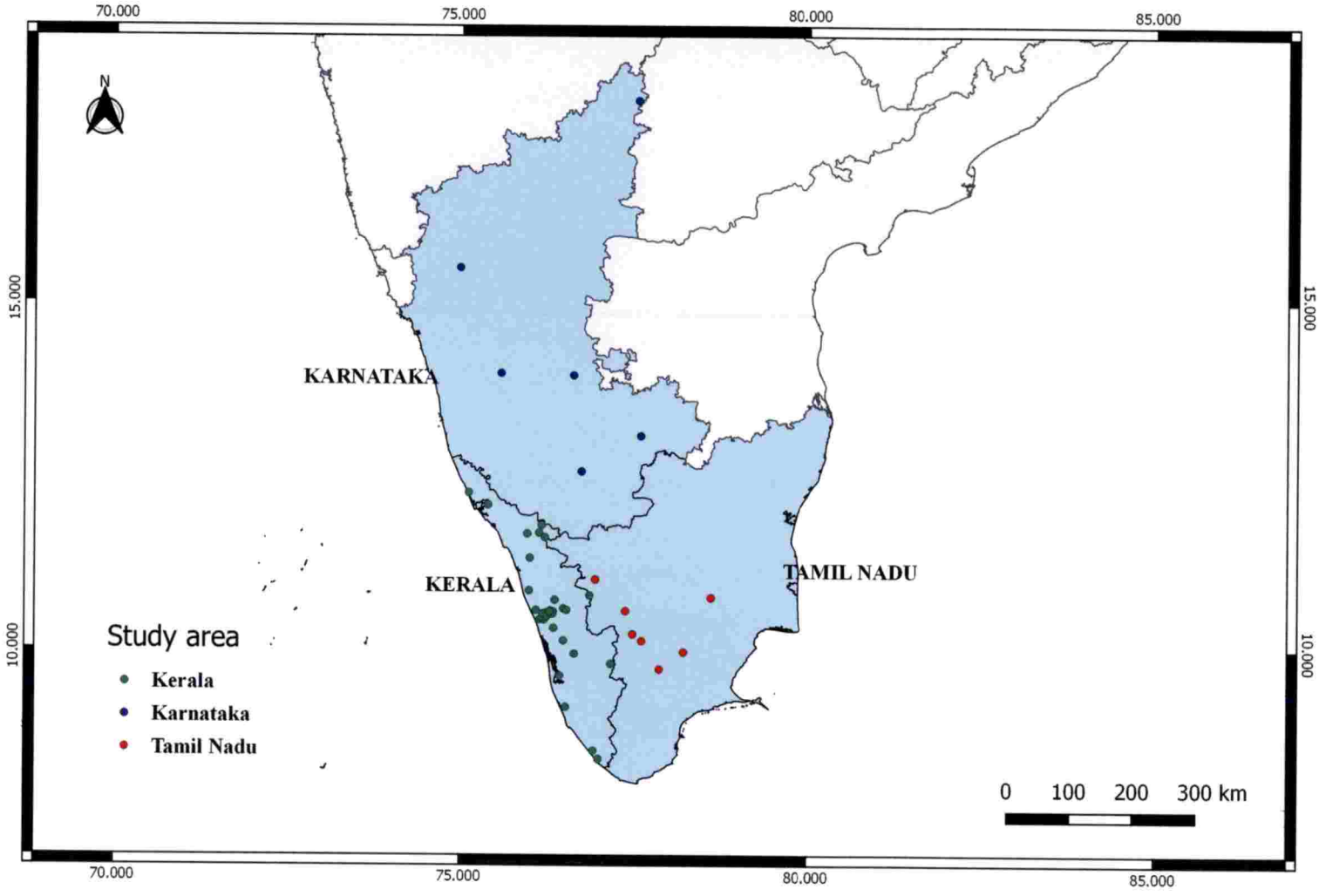

Fig. 1. Study Area and locations surveyed

3. 1. 1. 1. 3. Preservation of specimens

The preservation technique varied with nature of insects and purpose for which it was used.

3. 1. 1. 1. 3. 1. Dry preservation

The specimens were dry preserved for morphological studies. Aspirator was used to collect the beetles and beetles were killed immediately after collection. In case of long collection trips, where immediate mounting was not possible after killing, the specimens were transferred to small paper cylinders, made by rolling the butter paper and plugging both ends with cotton. Paper cylinders were used even to store dry specimens. The collection data was also noted.

The specimens were mounted on triangular card points prepared by cutting white ivory cards. The card points were held by insect pins of "size 1". The pointed end of each card point was slightly bent using forceps and the right side of thorax of the specimen was glued to the bent area of the card points using Fevicol®. The specimens were provided with a unique accession number which give information on the location and plants from which it was collected along with the date of collection. Later, proper labelling was made with locality, date, collector's name and associated plant. The specimens were then dried in oven at 50- 55^{0}C for 5-6 days and stored in insect cabinet boxes for further study.

3. 1. 1. 1. 3. 2. Wet preservation

Wet preserved specimens were used for molecular studies. The beetles were transferred to plastic vials containing 99 per cent ethyl alcohol after collection and stored at -80^{0}C. Maximum effort was taken to store specimen at -80^{0}C immediately after transferring it to alcohol. The specimens were labelled with accession number and proper collection data. The details of the samples used for DNA isolation, which are mentioned as accession numbers in Chaper 4 .2 are given in Appendix II.

3. 1. 1. 1. 3. 3. Preservation of prey

The associated prey collected with Scymnini were mealybugs, aphids, scales and whiteflies, which were preserved in 70 per cent ethyl alcohol. Mealybugs and aphids were identified by Dr. Sunil Joshi, National Bureau of Agricultural Insect Resources, Bengaluru.

Mites associated with Stethorini, were collected along with the infested leaf samples in polythene bags. Permanent slides of mites were prepared by mounting separately adult female and male mites dorsally in a drop of Hoyer's medium on glass slides. Male mites were also mounted in lateral position (Henderson, 2001) for observing the shape of the aedeagus, a key character for species level identification. The slides were then labeled with details *viz.* host, locality, date of collection, and collector's name. The slides were then dried at 40-45^{0}C for 5-6 days in hot air oven. After proper drying, slides were sealed well using transparent nail polish and later utilized for identification of species. The mites were identified by Dr. Haseena Bhaskar, All India Network Project on Agricultural Acarology, College of Horticulture, Kerala Agricultural University, Vellanikkara.

3. 1. 1. 2. Other sources of coccinellid material

Specimens in the collection of Department of Agricultural Entomology, College of Horticulture, Vellanikkara and All India Network Project on Agricultural Acarology, Department of Agricultural Entomology, University of Agricultural Sciences, Bengaluru were examined for the present study.

3. 1. 2. Morphological characterisation

3. 1. 2. 1. Preparation of genitalia and other parts

The male specimens were first softened by immersing in warm soap water for 45 min. to 1 h depending on the age of the specimen. The abdomen was then gently detached by inserting a minuten pin between metasternum and first abdominal ventrite. The abdomen was then transferred to 10 per cent aqueous solution of potassium hydroxide and incubated at 45^{0}C for 2-6 h depending on the chitinisation of the specimen. In some cases, the specimens were also left overnight

in cold potassium hydroxide for clearing. After digestion, the abdomen was transferred to a cavity block containing distilled water and digested tissues were pressed out with the help of fine needles under a stereomicroscope. This was then placed in glacial acetic acid for a minute, to neutralize the alkali. Again after washing in distilled water twice, the abdomen was transferred to a drop of glycerine placed in a cavity slide under a stereomicroscope. Genitalia was then pulled out using a minuten pin mounted on spent ball point pen refill. The penis was gently taken out from the penis guide. Genital segments were also separated from the abdominal segments. For those specimens, for which the genitalia was found to be very pale or over digested, traces of acid fuchsin was used to stain, which could facilitate the visibility.

Other appendages like antennae, mouth parts, prosternum and hind legs were also similarly extracted after dissecting them under a stereomicroscope.

Similarly, female genital segments and spermatheca were dissected out under stereomicroscope after digesting the abdomen. For Stethorini, the hemisternite was separated out from the genital segments for further study.

After examination, genitalia and other parts were stored in vials in a drop of glycerine.

3. 1. 2. 2. Illustrations and photomicrography

The illustrations of antenna, labrum, mandible, maxilla, labium, prosternum, hind tarsus, first abdominal ventrite, tegmen, penis, genital segment of male and female, spermatheca and hemisternite were made using *camera lucida* attached to a phase contrast microscope (Olympus BX 51) after placing the dissected parts in a drop of glycerine. Photographs of the whole specimens were taken with a camera attached to Stereo Zoom Microscope (Leica EZ4HD and Leica M205C). Composite images were generated from image stacks using Combine ZM software.

3. 1. 2. 3. Morphometrics

Measurements of ten randomly selected males and females were taken separately, unless fewer specimens were available. The measurements were made using image analyzing software, Leica Application System (LAS), attached to Stereo Zoom Binocular Microscope (Leica EZ4 HD). The following measurements were taken (Slipinski, 2007).

Total length (TL)	: Distance from the anterior end to the posterior end of the body
Total width (TW)/ Elytral width (EW)	: Distance across both elytra at their widest point
Pronotal length (PL)	: Distance from the middle of anterior margin to the base of pronotum
Pronotal width (PW)	: Width at the widest point of pronotum
Elytral length (EL)	: Elytral length along suture from apex to base including scutellum

3. 1. 2. 4. Description

Descriptions of all genera and species were provided in detail. Both male and female genitalia descriptions were provided wherever both sexes were available.

3. 1. 2. 5. Terminology

Terminology used for the description of taxa and preparation of key follow from Sasaji (1971) and Slipinski (2007)

Abdominal ventrite	:	individual ventrite of the abdomen
Aedeagus	:	penis and tegmen are together referred as aedeagus
Antennal club	:	enlarged distal antennomeres
Antennomere	:	the individual segments of antenna
Base of elytron	:	the area of elytron directly behind the pronotum
Cornu	:	part of spermatheca

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Elytral suture	:	both elytra touch each other at the median line of the body in its entire length
Epipleuron	:	the inflexed lateral part of the elytron
Fovea	:	a depression on the surface of a sclerite usually accommodating part of a leg or antenna
Frons	:	a single sclerite on the upper front part of head capsule
Funicle	:	third to the last segment of the antenna
Genital segments of male	:	genital segments of the male consists of the ninth and tenth tergites, the ninth ventrite and a pair of the ninth pleurites
Genital segments of female	:	genital segments of female consists of ninth tergite, pair of the ninth pleurites and a pair of hemisternites and these together form an ovipositor
Hemisternite	:	genital segments of female which are paired
Infundibulum	:	internal genital organ of female which may be cylindrical or sometimes absent
Nodulus	:	part of spermatheca to which the sperm duct is inserted
Palpomere	:	individual segments of a palp
Parameres	:	paired lateral lobes of tegmen
Pedicel	:	the second segment of antenna
Penis	:	tubular part of aedeagus, also termed as "sipho' and curved with a T- shaped basal part which is capsular in shape
Penis guide	:	median piece of tegmen, also termed as basal lobe or median lobe. Penis guide is usually elongate spindle shaped and has a deep groove for the reception of penis at the ventral side
Phallobase	:	basal piece of tegmen, also termed as basal piece
Post coxal line (abdominal)	:	curved ridges on the lateral part of first abdominal ventrite. They lie behind the metacoxae
Prosternum	:	The central sclerite of the ventral side of the prothorax

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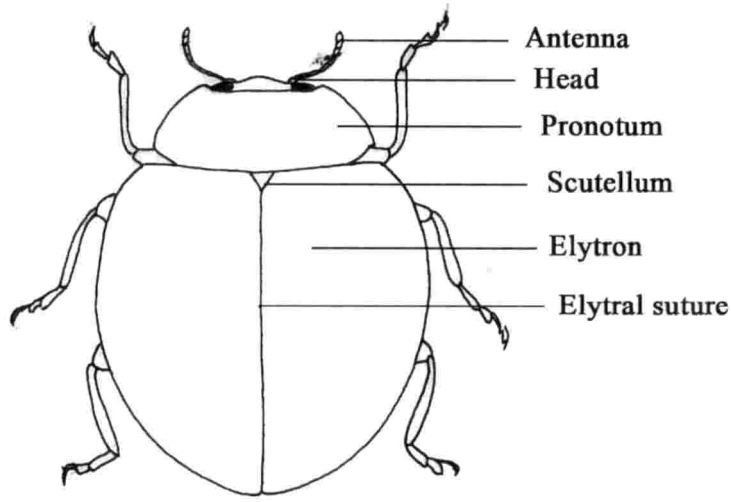
Prosternal process	:	a projection between the procoxae
Prosternal line	:	a paired ridge on the prosternal process
Ramus	:	part of spermatheca to which the accessory gland is inserted
Receptaculum seminis	:	Spermatheca
Scape	:	the first segment of the antenna
Scutellum	:	a small shield shaped sclerite lying between the elytral bases
Stylus	:	elongated structure on hemisternite
Tarsomeres	:	the individual segments of tarsus
Tarsal claws	:	a pair of sharp, hooked structures at the end of the tarsus
Tegmen	:	part of aedeagus which consists of phallobase, penis guide and parameres
Terminal palpomere	:	an enlarged palpomere at the end of the palp
Trabes	:	a median strut. further articulates with the ventral side of tegmen

The parts are illustrated in Fig. 2 and 3.

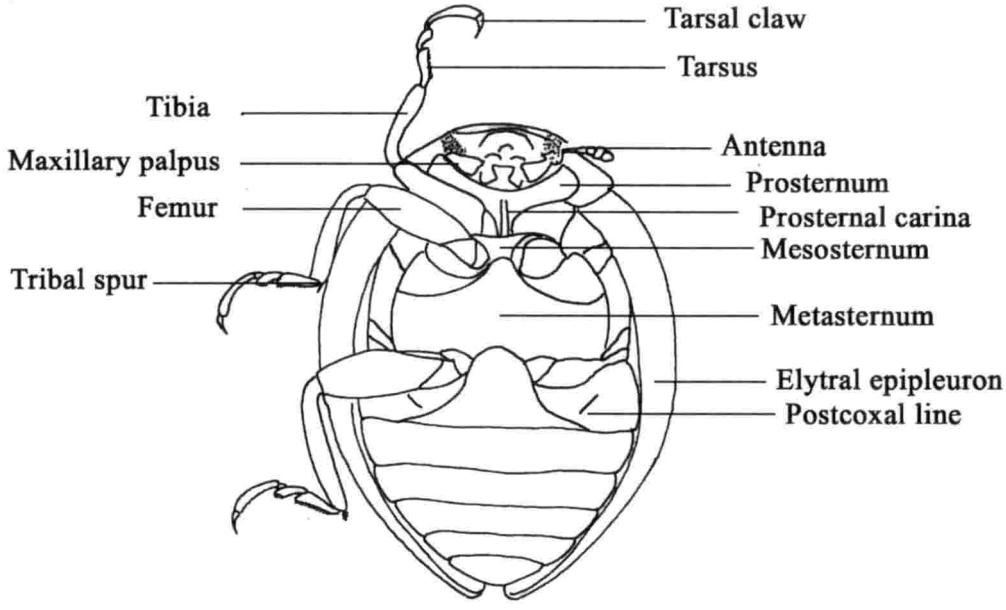
3. 1. 2. 6. Citation of collectors' name

While citing the collectors' names of the specimens studied, the following abbreviations were used.

CCG	:	Dr. C. C. Gowda, Department of Agricultural Entomology, University of Agricultural Sciences, Bengaluru
NU	:	Dr. Najitha Ummar, Department of Agricultural Entomology, College of Horticulture, Vellanikkara
SB	:	Sanju Balan, Department of Plant Pathology, College of Horticulture, Vellanikkara
SN	:	Dr. Sreenivasa, N., Department of Agricultural Entomology, University of Agricultural Sciences, Bengaluru



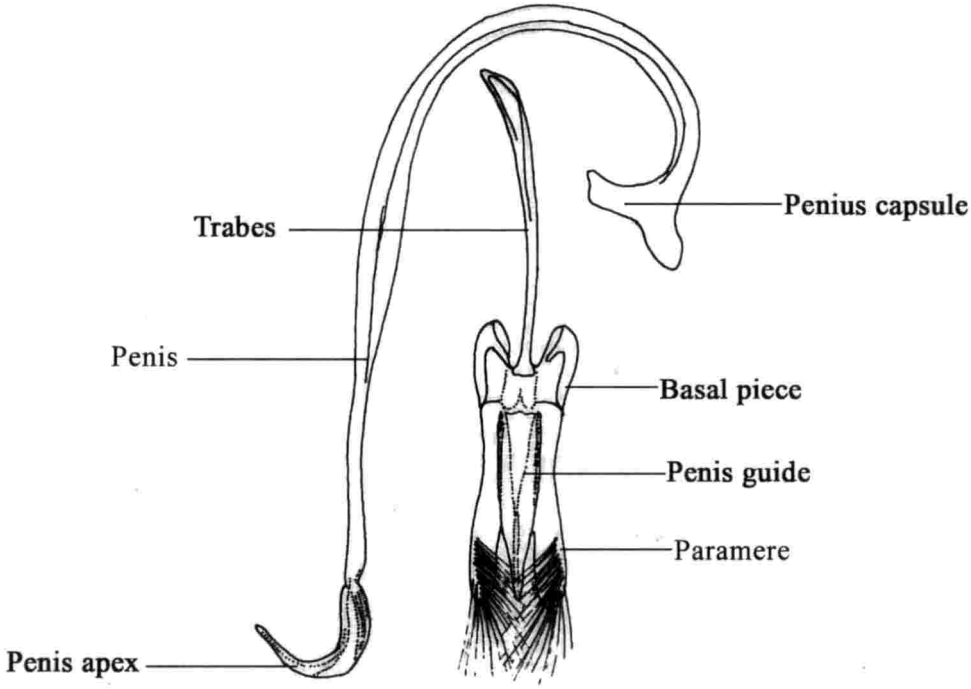
2a. Habitus - dorsal aspect



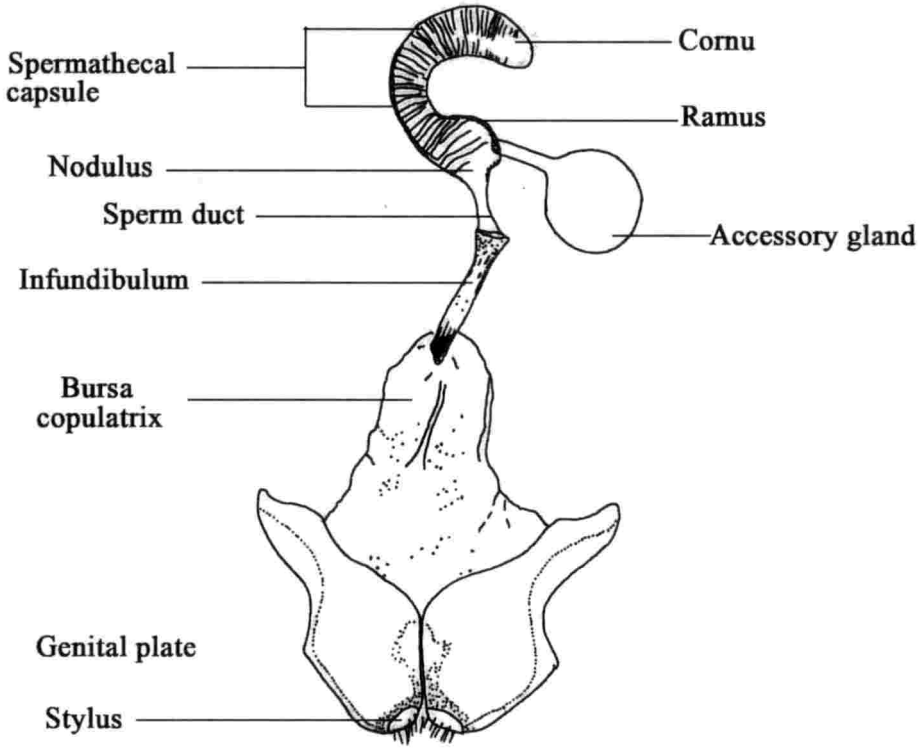
2b. Habitus - ventral aspect

Fig. 2. Body parts of Coccinellidae

(Redrawn from Gordon, 1985)



3a. Male genitalia



3b. Female genitalia

Fig. 3. Genitalia of Coccinellidae

(Redrawn from Gordon, 1985)

VCV : Vidya C.V., Department of Agricultural Entomology, College of Horticulture, Vellanikkara

3.1.3. Identification

The species identifications were done based on the available literature and taxonomic keys. Identification of Scymnini and Stethorini are based on Kapur (1948, 1950, 1961, 1967), Sasaji (1971), NBAIR (2013), Chen *et al.* (2015a, 2015b) and Poorani (2015a, 2017). After preliminary identification, this was later confirmed in consultation with Dr. J. Poorani, National Research Centre for Banana, Tiruchirappalli, Tamil Nadu.

3. 1. 4. Depositories

At present, all the specimens used in this study were deposited in the collection of the Department of Agricultural Entomology, College of Horticulture, Vellanikkara.

3. 1. 5. Distribution of species

The location of collection of the species recognised during present study within Kerala, Karnataka and Tamil Nadu were used for the preparation of distribution map. The distribution map was prepared using Quantum GIS software.

3.2. Taxonomic key for the identification of species

A character table was prepared for different species of Scymnini and Stethorini based on the characters studied. A dichotomous taxonomic key was then prepared for identification of species of Scymnini and Stethorini separately with the help of the character table.

3. 3. DNA barcoding of species of Stethorini

3. 3. 1. DNA isolation

The DNA was extracted from the specimens preserved in 99 per cent alcohol using Qiagen DNeasy® blood and tissue kit. The specimen was first washed with

distilled water and abdomen was separated by inserting sterilized insulin needle between metasternum and first abdominal ventrite under stereomicroscope. The remaining parts were used for extraction of DNA following manufacturer's protocols by standardising the time of incubation. The abdomen separated was preserved as morphological vouchers in small vials in a drop of glycerine and labelled with the accession number. This was later slide mounted in glycerine for confirmation of the species. The voucher specimens are deposited in the Department of Agrl. Entomology, College of Horticulture, Vellanikkara. For some specimens, the whole insect was used for DNA isolation. For each species, three samples were used for isolating the DNA, wherever the specimens were available.

3.3.2. Assessing the quality of the DNA

The quantity and quality of DNA samples were assessed using Nanodrop spectrophotometer by measuring the absorbance at wavelength of 260nm and 280nm (JenwayGenova Nano – Ver. 1.55.3). The AE buffer in the extraction kit, in which the isolated DNA was stored, was used as blank to measure the absorbance.

3. 3. 3. Mitochondrial cytochrome *c* oxidase subunit I amplification

Amplification of 658 bp region near the 5' terminus of the mitochondrial protein coding gene, mitochondrial cytochrome oxidase subunit I, was done by polymerase chain reaction (PCR) following standard protocol. Forward and reverse primers specific for COI locus, developed by Folmer *et al.* (1994) were used for amplification.

Locus	Primer	Sequence
COI	LCO 1490	5'-GGTCAACAAATCATAAAGATATTGG-3'
	HCO 2198	5'-TAAACTTCAGGGTGACCAAAAAATCA-3'

The reaction was carried out in 20 µl reaction volume containing 10 µl EmeraldAmp® GT PCR Master Mix, 9 µl of molecular water + template DNA and 0.5 µl each forward primer and reverse primer.

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The PCR was performed using a thermal cycler (Eppendorf Master cycler, gradient). Thermal profiling for the *COI* locus was carried out with the following programme. The annealing temperature was standardized by setting up a gradient PCR.

Initial denaturation	: 94° C for 4 min.	
Denaturation	: 94° C for 30 Sec.	35 cycles
Annealing	: 60.1 ° C for 1min.	
Extension	: 72 ° C for 2 min.	
Final extension	: 72° C for 10 min.	

3. 3. 4. Analysis and documentation of PCR product

The amplified product was analysed by Agarose Gel Electrophoresis (AGE) in 1.2 per cent agarose gel. 100 bp ladder (Thermo Scientific GeneRuler 100bp DNA Ladder) was used to assess the amplicon size. After electrophoresis, gel was documented using 'BioRad gel documentation system' and software 'Quantity one".

3. 3. 5. Sequencing of PCR product

Single, distinct amplicon obtained in PCR reaction was sequenced by outsourcing at AgriGenome Labs, Private Limited, Cochin.

3. 3. 6. Data analysis using *In-silico* tools

3. 3. 6. 1. Sequence analysis and annotation

The forward and reverse sequences for each specimens were assembled to form contigs using Clustal Omega (https://www.ebi.ac.uk/Tools/msa/clustalo/) and CAP3 sequence assembly programme (doua.prabi.fr/software/cap3). When Clustal Omega was used for sequence assemblage, the reverse sequences were converted using Reverse Complement (https://www.bioinformatics.org/sms/rev_comp.html). The assembled sequences were annotated to check the presence of stop codon using

MEGA 7 (www.megasoftware.net/) (Mathew, 2015). If stop codons were present, those were removed using Bio-Edit (www.mbio.ncsu.edu/BioEdit/bioedit.html), biological sequence alignment editor.

3. 3. 6. 2. Sequence homology analysis

Sequence homology was assessed using nucleotide BLAST (BLASTn) (https://blast.ncbi.nlm.nih.gov/Blast.cgi?PAGE_TYPE=BlastSearch), provided by the sequence similarity search programme, BLAST (Basic Local Alignment Search Tool) hosted by NCBI (National Centre for Biotechnology Information). The sequences with maximum identity, query coverage and least e- value in NCBI database were identified.

3. 3. 6. 3. Barcode gap identification

The assembled sequences were aligned using the multiple sequence alignment tool, Clustal Omega. Based on this, the barcode gaps were identified by analysing nucleotides. These barcode gaps were later summarised manually (Mathew, 2015).

3. 3. 6. 4. Calculation of pairwise distance

Pairwise distance was analyzed using MEGA 7. Assembled sequences were initially aligned using the option "Align by Clustal W" and distance estimation was carried out using the Kimura 2- Parameter.

3. 3. 6. 5. Construction of the phylogenetic tree

The sequences were initially aligned and the phylogenetic tree was constructed using phylogeny tool in MEGA 7. The statistical method adopted was maximum likelihood and the test of phylogeny was by Bootstrap method with 500 bootstrap replications. The tree was constructed with 21 sequences.

3. 3. 6. 6. Submission of sequences to NCBI GenBank

The annotated sequences were submitted to NCBI by creating account in NCBI BankIt (http://www.ncbi.nlm.nih.gov/WebSub/?tool=genbank). All the details regarding the specimens and sequences were given on submission.

3. 3. 6. 8. Submission to Barcode of Life Data Systems (BOLD)

The annotated sequences were submitted to Barcode of Life Data Systems (BOLD) (http://www.boldsystems.org/) for the generation of barcode for each specimen. Detailed information of specimens and sequences *viz*., specimen data, sequence data, traces, images and primer information were submitted for each sequence (Mathew, 2015).

Results

4. RESULTS

The study on "Systematics of the tribes Scymnini and Stethorini (Coleoptera: Coccinellidae) from south India" was conducted in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 2015-17. The study recognised 38 species belonging to six genera under the tribe Scymnini and two genera under the tribe Stethorini. The prey range and the distribution of the identified species were documented. DNA barcoding of the species under Stethorini was also carried out during the study. The major findings of the study are presented below.

4. 1. Taxonomy of the tribes Scymnini and Stethorini

4. 1. 1. List of species encountered during the study

Family Coccinellidae Latreille, 1807

Subfamily Scymninae Mulsant, 1846

Tribe Scymnini Mulsant, 1846

Genus *Axinoscymnus* H. Kamiya, 1963

Axinoscymnus puttarudriahi Kapur & Munshi, 1965

Axinoscymnus sp. 1

Genus *Cryptolaemus* Mulsant, 1853

Cryptolaemus montrouzieri Mulsant, 1853

Genus *Horniolus* Weise, 1900

Horniolus sororius Poorani, 2015

Genus *Nephus* Mulsant, 1846

Nephus regularis (Sicard), 1929

Nephus tagiapatus (Kamiya), 1965

Nephus sp. 1

Genus *Sasajiscymnus* Vandenberg, 2004

Sasajiscymnus sp.1

Genus *Scymnus* Kugelann, 1794

***Scymnus* (*Neopullus*) Sasaji, 1971**

Scymnus (*Neopullus*) *hoffmanni* Weise, 1879

Scymnus (*Neopullus*) sp. 1

***Scymnus* (*Pullus*) Mulsant, 1846**

Scymnus (*Pullus*) *castaneus* Sicard, 1929

Scymnus (*Pullus*) *coccivora* Ayyar, 1925

Scymnus (*Pullus*) *latemaculatus* Motschulsky, 1858

Scymnus (*Pullus*) *pyrocheilus* Mulsant, 1853

Scymnus (*Pullus*) *utilis* Hoang, 1982

Scymnus (*Pullus*) sp. 1

Scymnus (*Pullus*) sp. 2

Scymnus (*Pullus*) sp. 3

Scymnus (*Pullus*) sp. 4

Scymnus (*Pullus*) sp. 5

Scymnus (*Pullus*) sp. 6

Scymnus (*Pullus*) sp. 7

Scymnus (*Pullus*) sp. 8

Scymnus (*Pullus*) sp. 9

Scymnus (*Pullus*) sp. 10

***Scymnus* (*Scymnus*)** Kugelann, 1794

Scymnus (*Scymnus*) *nubilus* Mulsant, 1850

Species *incertae sedis*

Scymnus saciformis Motschulsky, 1858

Scymnus sp. 1

Tribe Stethorini Dobzhansky, 1924

Genus *Parastethorus* Pang & Mao, 1975

Parastethorus indira (Kapur), 1950

Genus *Stethorus* Weise, 1885

***Stethorus* (*Allostethorus*) Iablokoff-Khnzorian, 1972**

Stethorus (*Allostethorus*) *forficatus* Poorani, 2017

Stethorus (*Allostethorus*) *pauperculus* (Weise), 1895

Stethorus (*Allostethorus*) *tetranychi* Kapur, 1948

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Stethorus (*Allostethorus*) sp. 1

***Stethorus* (*Stethorus*) Weise, 1885**

Stethorus (*Stethorus*) *rani* Kapur, 1948

Stethorus (*Stethorus*) sp. 1

Stethorus (*Stethorus*) sp. 2

Stethorus (*Stethorus*) sp. 3

Species *incertae sedis*

Stethorus keralicus Kapur, 1961

4. 1. 2. Morphological characters of the tribes Scymnini and Stethorini

The general morphological characters of the subfamily and tribes studied are described below.

4. 1. 2. 1. Subfamily Scymninae Mulsant, 1846

Scymniens Mulsant, 1846: 210.

Scymninae Della Beffa, 1912: 168.

Type genus: *Scymnus* Kugelann, 1794

Body usually small, sometimes medium sized, dorsum pubescent; pronotum and elytra compactly articulated and the elytral base not much broader than pronotal base; antenna short, usually very short, at most about two-thirds as long as head width, situated more or less ventrally; clypeus not strongly expanded laterally; terminal palpomere of maxillary palp not strongly securiform; prosternum not deeply concave or roundly convex at anterior margin; middle coxa usually broadly separated; elytral epipleura narrow and short; tarsi trimerous or cryptotetramerous.

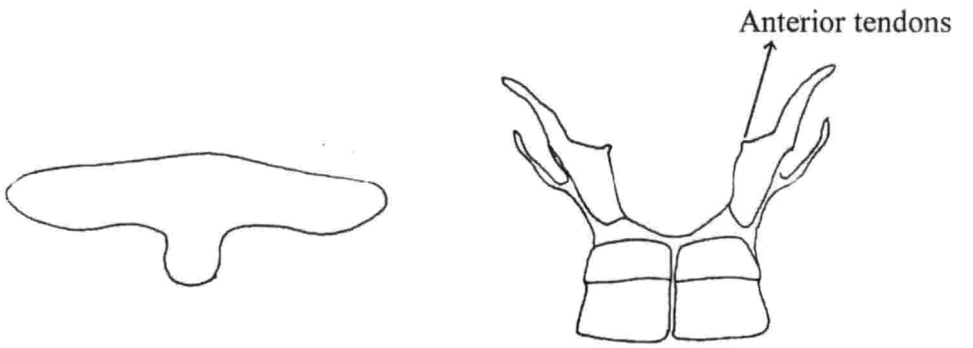
Key to the tribes, Scymnini and Stethorini collected during the study

1 Body small; antenna with 9 to 11 antennomeres, relatively short; terminal palpomere of maxillary palp parallel sided or weakly divergent; anterior margin of prosternum flat or weakly excavated (Fig. 4.1a); prosternal carina present or absent; metendosternite with narrowly separated anterior

4. 1a. Prosternum

4. 1b. Metendosternite

4. 1. Scymnini



4. 2a. Prosternum

4. 2b. Metendosternite

4. 2. Stethorini

Fig. 4. Morphology of prosternum and metendosternite of Scymnini and Stethorini

tendons (Fig.4.1b); tegmen of male genitalia not very slender .....**Scymnini** Mulsant

_ Body very small; antenna with 10 to 11 antennomeres; terminal palpomere of maxillary palp slightly convergent towards apex; anterior margin of prosternum roundly convex (Fig.4.2a); prosternal carina absent; metendosternite with broadly separated anterior tendons (Fig. 4.2b); tegmen of male genitalia usually slender, rarely stout .....**Stethorini** Dobzhansky

4. 1. 2. 1. 1. Tribe Scymnini Mulsant, 1846

Scymniaires Mulsant, 1846: 210.

Scymnini Costa 1849: 9.

Type genus: *Scymnus* Kugelann, 1794

Body small, very rarely medium sized; round, oval or oblong, hemispherical to slightly convex; varied colour and elytral pattern; dorsum and eye pubescent; antenna composed of nine to eleven antennomeres, rather short, terminal antennomeres forming the club; terminal palpomere of maxillary palp nearly parallel sided or weakly divergent apically; anterior margin of prosternum weakly excavated; elytral epipleura narrow, without foveae; tarsi trimerous or cryptotetramerous; metendosternite with narrowly separated anterior tendons and a rather long stalk; abdomen with six visible segments; tegmen of male genitalia not very slender; hemisternites of female elongate triangular to transverse oval with a distinct stylus.

Six genera were identified during the study which can be recognised with the following key.

Key to the genera of the tribe Scymnini collected during the study

1 Body medium sized, usually more than 3.5 mm; prosternum enlarged, produced anteriorly to cover the mouth parts.....
.....***Cryptolaemus*** Mulsant

_ Body relatively small, less than 3mm; prosternum not enlarged, not covering the mouth parts 2

2(1) Prosternum with inverted Y-shaped carina (Fig. 8F); scutellum large .....***Horniolus*** Weise

_ Prosternum without inverted Y-shaped carinaa; scutellum relatively small.....3

3(2) Prosternum with narrow basisternum (Fig. 5F), prosternal process short and broad with carina; tarsi trimerous.....4

_ Basisternum of prosternum broad (Fig. 18F), prosternal process T-shaped with carina or broad without carina or with indistinct carina; tarsi trimerous or cryptotetramerous.....5

4(3) Antenna with 11 antennomeres; post coxal line complete; tegmen with extremely short penis guide (Fig. 5J); penis short without distinct process at the base .....***Axinoscymnus*** H. Kamiya

_ Antenna with 9 antennomeres; post coxal line incomplete; tegmen with long penis guide (Fig. 12I); penis with distinct process at the base .....***Sasajiscymnus*** Vandenberg

5(3) Antenna with 10 or 11 antennomeres, scape and pedicel not fused; prosternum with distinct carina; tarsi trimerous or cryptotetramerous; post coxal line of first abdominal ventrite complete (Fig. 13H) or incomplete without reaching the base of first abdominal ventrite, apex curved upwards (Fig. 30H).....***Scymnus*** Kugelann

_ Antenna with 10 antennomeres; scape and pedicel fused; prosternum without carina or with indistinct carina; tarsi trimerous; post coxal line of first abdominal ventrite incomplete, extending near to the lateral margin of ventrite, either parallel to posterior margin or with apex curved forward (Fig. 11H).....***Nephus*** Mulsant

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4. 1. 2. 1. 1. 1. Genus *Axinoscymnus* H. Kamiya, 1963

Axinoscymnus H. Kamiya, 1963: 127.

Type species: *Axinoscymnus beneficus* H. Kamiya, 1963, by original designation

Body small, oval, dorsum convex; antenna moderate in length; terminal maxillary palpomere distinctly divergent apically; prosternum with narrow basisternum; prosternal process short with carina; leg trimerous; post coxal line of first abdominal ventrite complete; penis short and stout without a distinct process at the base; penis guide short.

Two species of *Axinoscymnus* were recognised during the present study, of which one is identified only upto genus as the male specimen was lacking. The species recognised upto species level was *A. puttarudriahi*.

Remarks: Genus *Axinoscymnus* is closely related to the genus *Sasajiscymnus*. These two genera can be separated from other genera under Scymnini by the presence of tarsi with three tarsomeres and prosternum with narrow basisternum and short prosternal process. However, these two genera can be separated by the number of antennomeres, nature of post coxal line and male genitalia. Members of *Axinoscymnus* differ from *Sasajiscymnus* with the presence of antenna with 11 antennomeres, complete post coxal line on first abdominal ventrite and male genitalia with short stout penis without distinct process at the base and extremely short penis guide, whereas species of *Sasajiscymnus* bears antenna with nine antennomeres, incomplete post coxal line on first abdominal ventrite and elongate penis, with a distinct process at the base and usually penis guide longer than parameres.

Key to the species of the genus *Axinoscymnus* collected during the study

1 Pronotum pale yellow to yellowish brown with irregular faded patches; elytra light brown to dark brown with large, oval, yellow median spots; spermatheca bulbous in shape.....
.....***Axinoscymnus puttarudriahi* Kapur & Munshi**

_ Pronotum black with orange coloured anterior and lateral margin; elytra black with apex orange in colour, spermatheca elongated..... ..... ***Axinoscymnus* sp.1**

4. 1. 2. 1. 1. 1. 1. *Axinoscymnus puttarudriahi* Kapur & Munshi, 1965 (Plate 1a; Fig. 5)

Axinoscymnus puttarudriahi Kapur & Munshi, 1965: 5.

Diagnosis: This species can identified by light brown to dark brown elytra with large, oval, yellow median spots. Male genitalia is with short penis guide and penis without any distinct process.

Description: Body small, oblong oval, moderately convex, narrowed towards apex; head yellowish with pale yellow mouth parts; pronotum pale yellow to yellowish brown with irregular faded patches; scutellum brownish yellow; elytra light brown to dark brown with large, oval, yellow median spots; head with narrow frons; antenna with 11 antennomeres; terminal maxillary palpomere securiform; prosternal process with posteriorly divergent carina; tarsi trimerous; post coxal lines on first abdominal ventrite complete.

Male genitalia: Tegmen with short penis guide; parameres elongate oval with a few short hairs at the apex; penis short and stout, gently curved at the basal 1/4th region, without any distinct process at the base.

Female genitalia: Genital plates much broader towards apex; spermatheca bulbous in shape.

Measurements: Total length: 1.59 (1.45 - 1.63) mm, total width: 1.04 (0.99 - 1.08) mm, TL/TW: 1.48 (1.41 - 1.52), PL/PW: 0.49 (0.42 - 0.53), EL/EW: 1.18 (1.14 - 1.26), EW/PW: 1.33 (1.28 - 1.40).

Material: India: Kerala: 5♂, 6♀, Moorkkinikkara, 03.xi.2015 (VCV); 4♂, 7♀, Vellanikkara, 12.xi.2015 (VCV); 2♂, 1♀, Chazhur, 17.xi.2015 (VCV); 7♂, 10♀, Vadakarapathy, 02.xii.2015 (VCV); 6♂, 1♀, Vandazhy, 09.xii.2015 (VCV); 3♂, 9♀, Tavanur, 12.xii.2015 (VCV); 3♂, 1♀, Padannakkad, 20.xii.2015 (VCV); 4♂, 6♀, Panniyur, 21.xii.2015 (VCV); 1♂, Marakkal, 25.ii.2016 (VCV); 1♀, Avinissery, 26.ii.2016 (VCV); 1♂, 1♀, Chalakkudy, 11.iii.2016 (VCV); 3♂, 5♀,

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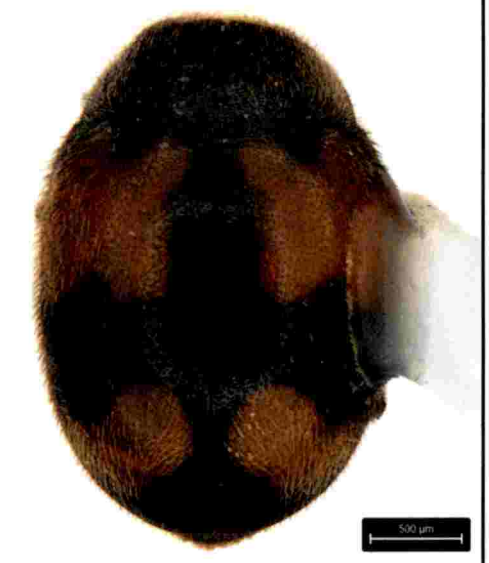
a. *Axinoscymnus puttarudriahi*

b. *Axinoscymnus* sp.1

c. *Cryptolaemus montrouzieri*



d. *Horniolus sororius*

Plate 1. Species of Scymnini

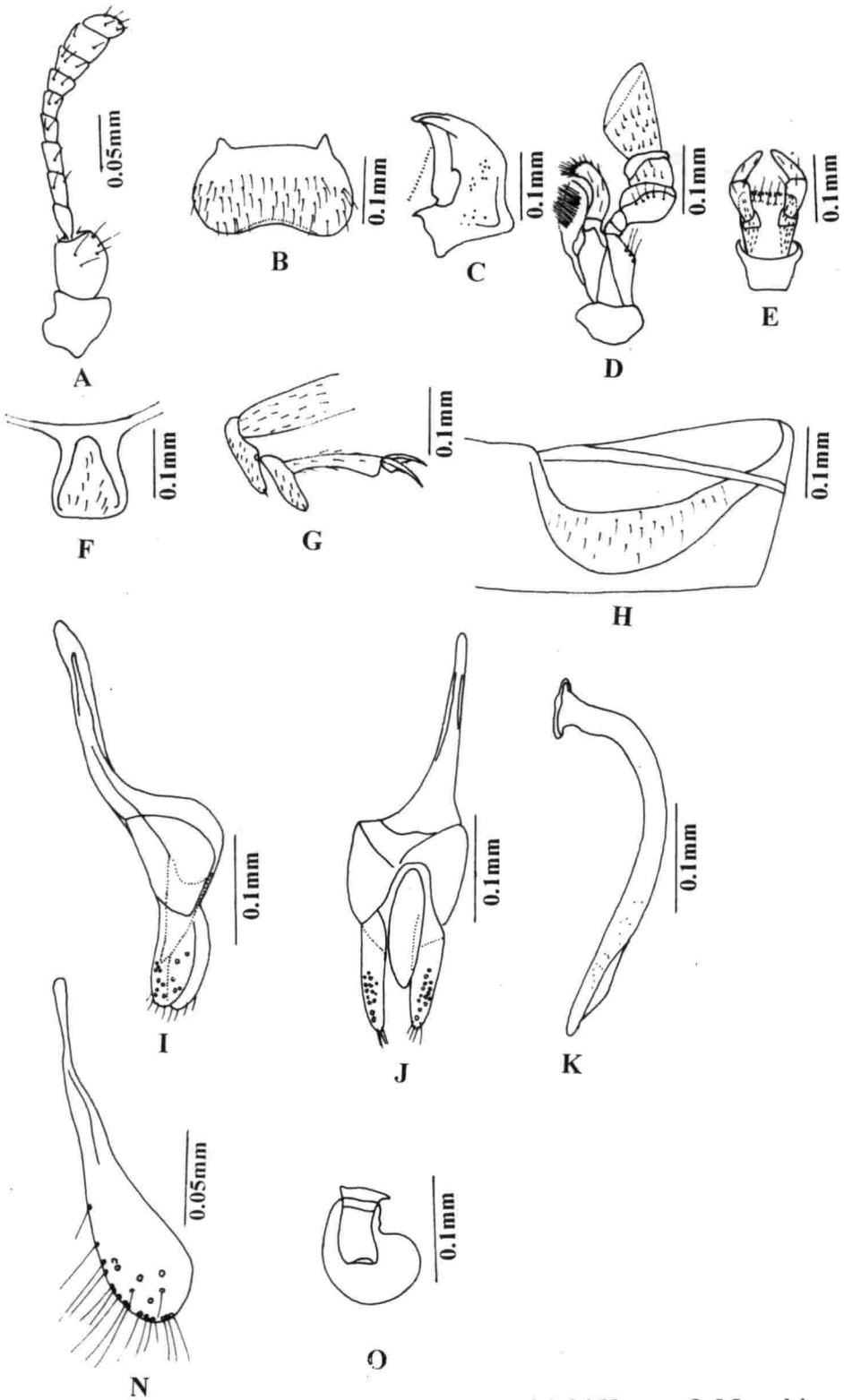


Fig. 5. *Axinoscymnus puttarudriahi* Kapur & Munshi

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; N. hemisternite of female; O. spermatheca

Kumarakom, 15.iii.2016 (VCV); 4♂, 6♀, Vellayani, 19.iv.2016 (VCV); **Karnataka:** 4♂, 1♀, Bengaluru, 25.xii.2015 (VCV); 1♀, Dharwad, 16.ix.2016 (VCV); **Tamil Nadu:** 7♂, 11♀, Tiruchirappalli, 23.i.2016 (VCV); 1♀, Madurai, 09.ix.2016 (VCV).

Prey/Associated host: *Aleurodicus dispersus* Russell on banana, chilli, guava, tapioca; *Bemisia tabaci* (Gennadius) on *Achyranthes aspera*, chilli, star gooseberry.

Remarks: *Axinoscymnus puttarudriahi* was found to be widely distributed in the study area. This is is the only species of *Axinoscymnus* reported from India so far. These were always found associated only with whiteflies.

4. 1. 2. 1. 1. 1. 2. *Axinoscymnus* sp.1 (Plate 1b; Fig. 6)

Diagnostic characters: Body small, short oval, moderately convex; head yellowish brown; pronotum black with orange coloured anterior and lateral margin; elytra black with orange apex; terminal maxillary palpomere divergent; prosternal process short with posteriorly divergent carina; tarsi trimerous; post coxal lines on first abdominal ventrite complete.

Female genitalia: Genital plates much broader towards apex; spermatheca slightly elongated.

Measurements: Total length: 1.69 mm, total width: 1.19 mm.

Material: India: Kerala: 1♀, Kayamkulam, 09.iii.2016 (VCV).

Prey/Associated host: on tapioca (prey not known).

Remarks: This species differs from *A. puttarudriahi* in external appearance and elytral pattern. The male genitalia could not be studied due to the unavailability of male specimen. The spermatheca of this species is elongated than that of *A. puttarudriahi*, which is bulbous in shape. This is the first report of a species of *Axinoscymnus* other than *A. puttarudriahi* from Indian subregion.

4. 1. 2. 1. 1. 2. Genus *Cryptolaemus* Mulsant, 1853

Cryptolaemus Mulsant, 1853a: 268.

Type species: *Cryptolaemus montrouzieri* Mulsant, 1853, by monotypy.

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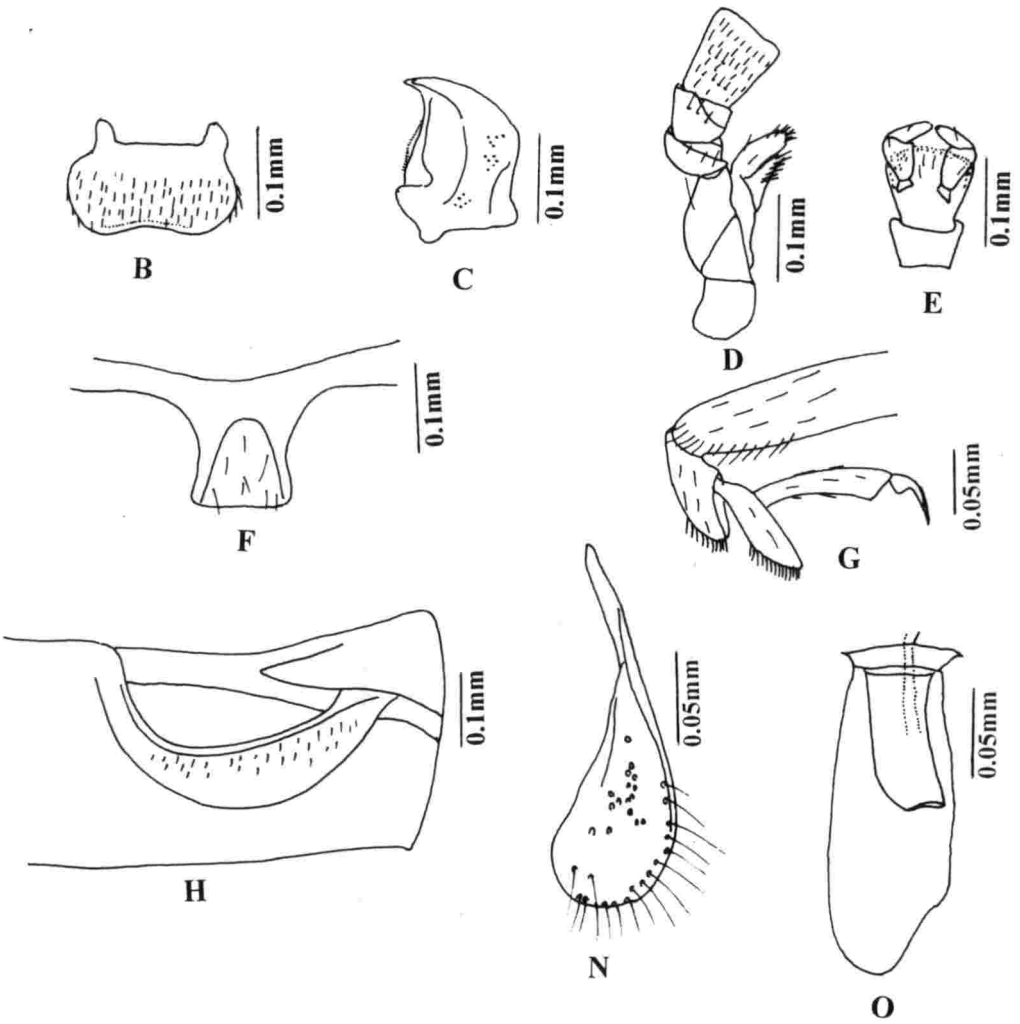

Fig. 6. *Axinoscymnus* sp. 1

B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; N. genital segment of female; O. spermatheca

Body medium sized, oval, convex and densely pubescent; antenna with 10 antennomeres; terminal maxillary palpomere distinctly divergent; prosternum broadly rounded to cover the mouth parts; prosternal process relatively shorter, carina nearly parallel, extending less than halfway to anterior margin; tarsi trimerous; post coxal line of first abdominal ventrite complete; parameres of male genitalia with distinct setae; female genitalia with long and triangular hemisternites; spermatheca worm like without clear ramus or nodulus.

Only one species identified under *Cryptolaemus* during the study was *C. montrouzieri*.

Remarks: *Cryptolaemus* is easily distinguished by its relatively larger size compared to other genera. Prostenum is enlarged and produced anteriorly to cover the mouth parts. This is separated from *Axinoscymnus*, *Horniolus*, *Nephus, Sasajiscymnus* and *Scymnus* by the presence of weak, short prosternal carina. *Cryptolaemus* can be differentiated from *Nephus* by the presence of complete post coxal line on first abdominal ventrite.

4. 1. 2. 1. 1. 2. 1. *Cryptolaemus montrouzieri* Mulsant, 1853 (Plate 1c; Fig. 7)

Cryptolaemus montrousieri Mulsant, 1853a: 268.

Cryptolaemus montrouzieri: Crotch, 1874: 204 (emend.). -Korschefsky, 1931: 169 (cat.).-Puttarudriah *et al.*, 1952: 377 (introduced into India).- Sasaji, 1971: 93.- Gordon, 1985: 105.

Cryptolaemus montrouzieri montrouzieri: Booth & Pope, 1986: 706 (rev. and lectotype design.).

Diagnosis: This species is medium sized with reddish orange/orange yellow head and pronotum. Elytra is dark brown to black with reddish orange/orange yellow tip. Male genitalia with characteristic setae on the inner surface of parameres.

Description: Body medium sized, elongate oval, convex, head, pronotum, elytra pubescent; head, antenna, mouth parts and pronotun reddish orange /orange yellow; scutellum reddish orange or blackish brown to black; elytra dark brown to black with tip reddish orange/orange yellow; prosternum and abdominal ventrites are yellow to orange yellow, meso- and metasternum blackish; males with forelegs

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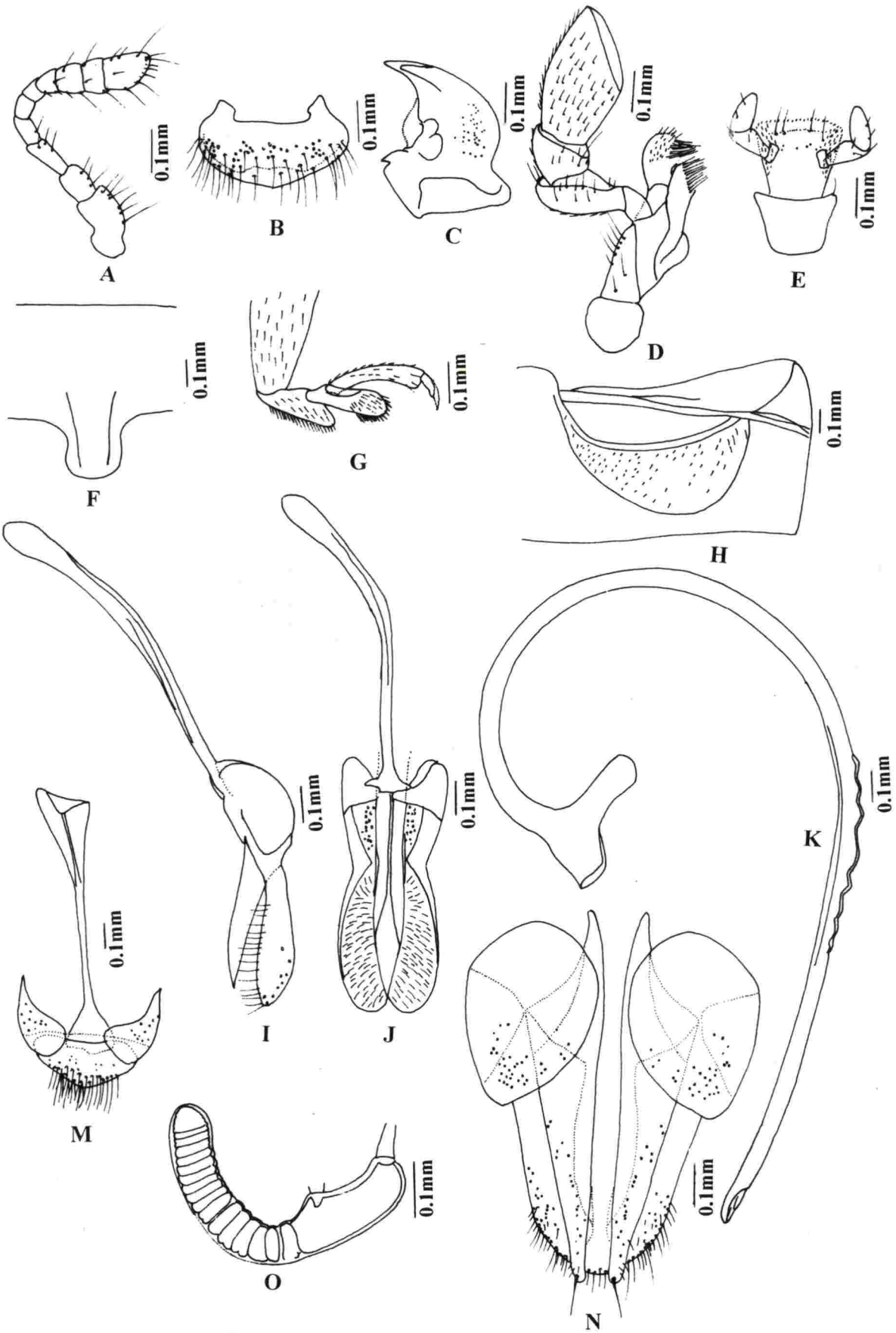

Fig. 7. *Cryptolaemus montrouzieri* Mulsant

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; M. genital segment of male; N. genital segment of female; O. spermatheca

reddish brown, middle legs and hindlegs blackish; in females all legs dark brown/blackish; antenna with 10 antennomeres, weakly clavate terminally; terminal maxillary palpomere distinctly divergent; prosternal process short, prosternal carina short, reaching less than halfway to anterior margin; tarsi trimerous; post coxal lines on first abdominal ventrite complete, strongly curved.

Male genitalia: Tegmen stout with penis guide shorter than parameres; parameres with characteristic setae on inner surface; penis guide acuminate; penis curved, outer margin of penis wavy towards middle $1/5^{th}$ portion; penis capsule well developed; apophysis of ninth abdominal sternite subtriangular distally.

Female genitalia: Hemisternites triangular, spermatheca slender, curved and worm like.

Measurements: Male: Total length: 4.08 (3.83 - 4.39) mm, total width: 2.94 (2.79 - 3.13) mm, TL/TW: 1.42 (1.38 - 1.47), PL/PW: 0.53 (0.43 - 0.59), EL/EW: 1.10 (1.02 - 1.16), EW/PW: 1.37 (1.26 - 1.49); **Female:** Total length: 4.31 (3.88 - 4.70) mm, total width: 3.05 (2.84 - 3.42) mm, TL/TW: 1.41 (1.34 - 1.48), PL/PW: 0.58 (0.52 - 0.69), EL/EW: 1.09 (1.01 - 1.21), EW/PW: 1.37 (1.27 - 1.45).

Material: India: Kerala: 5♂, 3♀, Ollur, 28.i.2017 (VCV); **Karnataka:** 8♂, 6♀, Bengaluru, 24.xii.2015, 26.xii.2015 (VCV); **Tamil Nadu:** 7♂, 5♀, Tiruchirappalli, 23.i.2016, 24.i.2016 (VCV); 3♂, 1♀, Madurai, 10.ix.2016 (VCV).

Prey/Associated host: *Ferrisia virgata* (Cockerell) on *Abutilon*, guava, *Jatropha*; *Paracoccus marginatus* Williams and Granara de Willink on papaya; *Planococcus* sp. on *Macaranga peltata*; mealybugs on *Casuarina*, grapes.

Remarks: This species is very much different from other species of Scymnini from south India with its bigger size and characteristic setae on the inner surface of parameres. This is a native of Indo-Australian region and was introduced to India.

4. 1. 2. 1. 1. 3. Genus *Horniolus* Weise, 1900

Horniolus Weise, 1900: 442.- Miyatake, 1963: 6.

Type species: *Horniolus dispar* Weise, 1900, by monotypy.

Body relatively medium in size, elongate oval, moderately convex, densely pubescent; antenna with 11 antennomeres, terminal five antennomeres wider

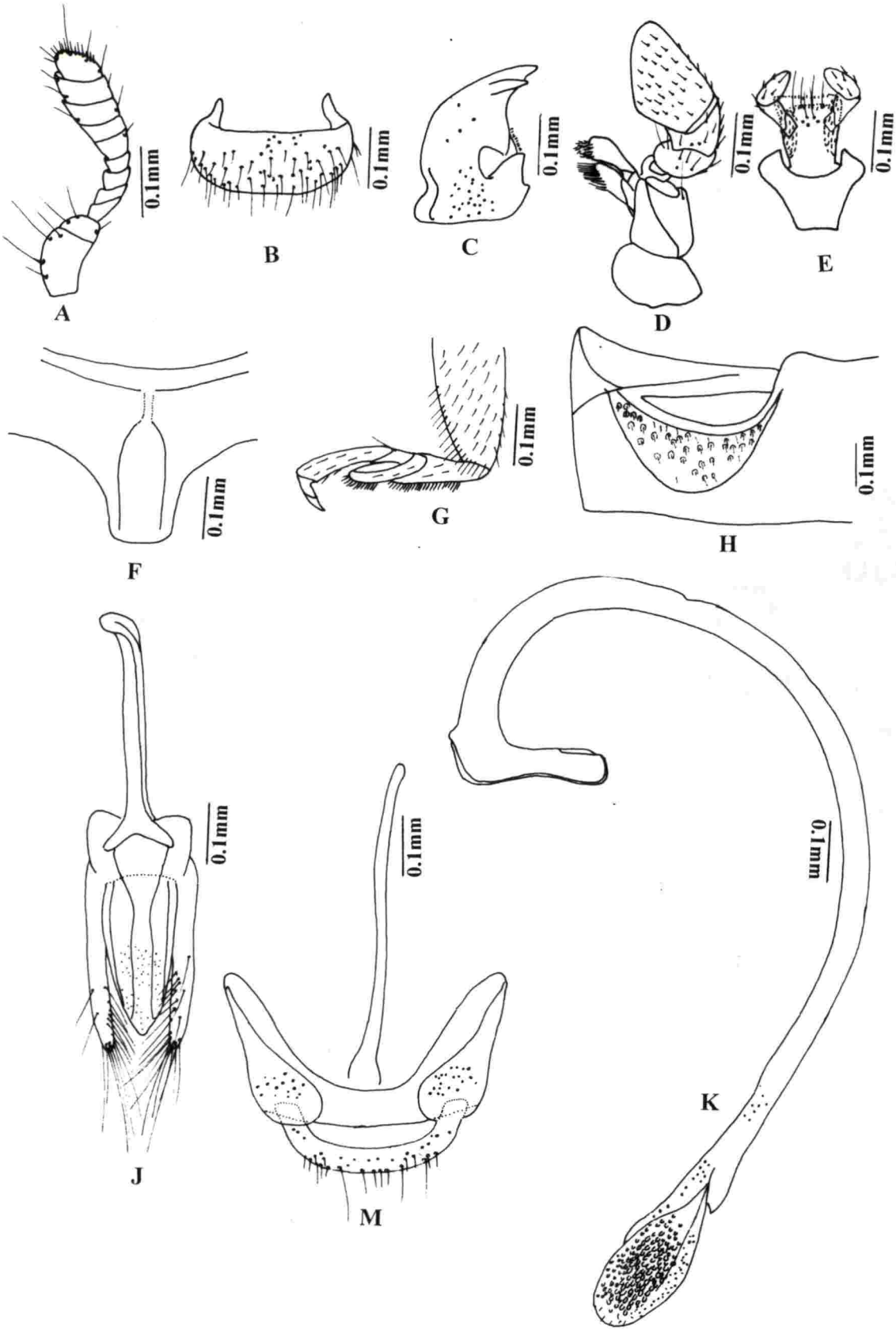

Fig. 8. *Horniolus sororius* Poorani

A.antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; J. tegmen, ventral; K. penis; M. genital segment of male

forming a club; labrum transverse, rounded at the anterior margin; terminal maxillary palpomere stout, weakly divergent apically and obliquely truncate; prosternum with prosternal process having an inverted Y-shaped carina, area enclosed by prosternal carina smooth; legs stout and hind femora flattened; tarsi cryptotetramerous; scutellum moderately large; abdomen with six ventrites; postcoxal lines of first abdominal ventrite complete.

Remarks: *Horniolus* is closely related to genus *Scymnus* especially *Scymnus* (*Pullus*) with 11 antennomeres, cryptotetramerous tarsi and complete abdominal post coxal line, but can be differentiated with an inverted Y-shaped carina on the prosternal process and relatively larger scutellum.

4. 1. 2. 1. 1. 3. 1. *Horniolus sororius* Poorani, 2015 (Plate 1d; Fig. 8)

Horniolus sororius Poorani, 2015a: 7.

Diagnosis: The species can be identified by the characteristic male genitalia with flattened, spatulate, densely spotted penis apex.

Description: Body medium sized, elongate oval, moderately convex, pubescent with yellowish hairs; head brown with dark brown mouth parts with tip of maxillary palp lighter; pronotum dark brown; elytra blackish brown with two pairs of orange yellow spots, first pair transverse, roughly quadrate, and second pair transverse and relatively smaller; ventral side reddish brown with pro-, meso- and metasternites dark; legs brownish black, tarsal segments testaceous; antenna with 11 antennomeres; terminal maxillary palpomere divergent; prosternal process with inverted Y-shaped carina; tarsi cryptotetramerous; post coxal line of first abdominal ventrite complete, area enclosed by post coxal line sparsely punctate.

Male genitalia: Tegmen with penis guide shorter than parameres; apex of parameres with elongate hairs; penis guide apically slightly asymmetrical, progressively narrowed towards apex; penis stout, basal 1/3rd portion curved, apex flattened, spatulate, densely spotted, penis capsule with prominent inner arm, outer arm lacking; apophysis of ninth abdominal sternite elongated without any dilation.

Measurements: Male: Total length: 2.34 mm, total width: 1.69 mm, TL/TW: 1.30, PL/PW: 0.55, EL/EW: 0.89, EW/PW: 1.25; **Female:** Total length: 2.79 mm, total width: 1.79 mm, TL/TW: 1.65, PL/PW: 0.56, EL/EW: 1.08, EW/PW: 1.31.

Material: India: Kerala: 1♂, 2♀, Pulpally, 11.ix. 2015 (NU).

Prey/Associated host: *Formicococcus polysperes* Williams on black pepper.

Remarks: *Horniolus sororius* has similar elytral pattern of *Scymnus* (*Pullus*) *latemaculatus* which is common species in south India, but can be distinguished with the presence of inverted Y-shaped carina on the prosternal process and male genitalia.

4. 1. 2. 1. 1. 4. Genus *Nephus* Mulsant, 1846

Scymnus (*Nephus*) Mulsant, 1846: 237.

Nephus: Motschulsky, 1866: 425.- Chapin, 1965: 200-201. Type species: *Coccinella quadrilunulatus* Illiger, 1798 (=*Sphaeridium quadrimaculatus* Herbst, 1783), by subsequent designation of Korschefsky, 1931.

Sidis Mulsant, 1850: 975 (as subgenus of *Scymnus*).-Gordon, 1976: 282 (as a subgenus of *Nephus*). Type species: *Scymnus* (*Sidis*) *binaevatus* Mulsant by subsequent designation of Korschefsky, 1931.

Nephus (*Bipunctatus*) Fursch, 1987: 66. Type species: *Scymnus bipunctatus* Kugelann, 1794.

Nephus (*Geminosipho*) Fursch, 1987: 68. Type species: *Nephus bielawskii* Fursch, 1965.

Nephus (*Parascymnus*) Fursch, 1987: 66 (*Parascymnus* Chapin, 1965 downgraded). Type species: *Parascymnus palauensis* Chapin, by original designation.

Aponephus Booth, 1991: 47. Type species: *Aponephus lentiformis* Booth, 1991, by original designation. -Synonymised by Poorani, 2002: 350.

Body small, oval, weakly to strongly convex and pubescent; antenna composed of 10 antennomeres with fused scape and pedicel and nine flagellomeres; terminal maxillary palpomere weakly divergent or nearly parallel sided; prosternal

process relatively broad, prosternal carina absent or short, indistinct and not extending to anterior margin; tarsi trimerous; post coxal line of first abdominal ventrite incomplete, extending near to the lateral margin of ventrite, either parallel to posterior margin or with apex curved forward.

Remarks: Genus *Nephus* is related to *Scymnus*, but is separated by the fused scape and pedicel and prosternal process without carina or with indistinct carina.

Key to the species of the genus *Nephus* collected during the study

1 Elytra black or brownish black with orange yellow apical region; prosternal carina absent (Fig. 11F).....***Nephus* sp. 1**

_ Elytra yellowish or brownish yellow, often with a dark patch at the base of elytra which extends along suture; prosternal carina short and indistinct (Fig. 10F).....2

2(1) Body elongate oval; parameres slender; apex of penis tapering without any distinct process (Fig. 10L).....***Nephus tagiapatus*** (Kamiya)

_ Body short oval; parameres not slender; apex of penis with a distinct process (Fig. 9L) .....***Nephus regularis*** (Sicard)

4. 1. 2. 1. 1. 4. 1. *Nephus regularis* (Sicard), 1929 (Plate 2a; Fig. 9)

Scymnus (*Nephus*) *regularis* Sicard, 1929: 183. -Korschefsky, 1931: 144 (cat.).

Nephus regularis: Chelliah, 1965: 166. (♂ genitalia figd.). -Pang & Gordon, 1984: 133 (redesc. & lectotype design.).

Diagnosis: This species can be distinguished by its short oval body, yellowish or brownish yellow elytra which is often with a dark patch at the base which extends along suture. Male genitalia with a distinct process at the penis apex.

Description: Body small, short oval and moderately convex, dorsum pubescent; head yellowish brown with yellowish brown to brown mouth parts; pronotum and scutellum yellowish brown; elytra yellowish brown to light orange brown with basal region and suture dark, very often with a black patch at the base; ventral side yellowish brown with dark pro-, meso- and metasternum; middle of first abdominal

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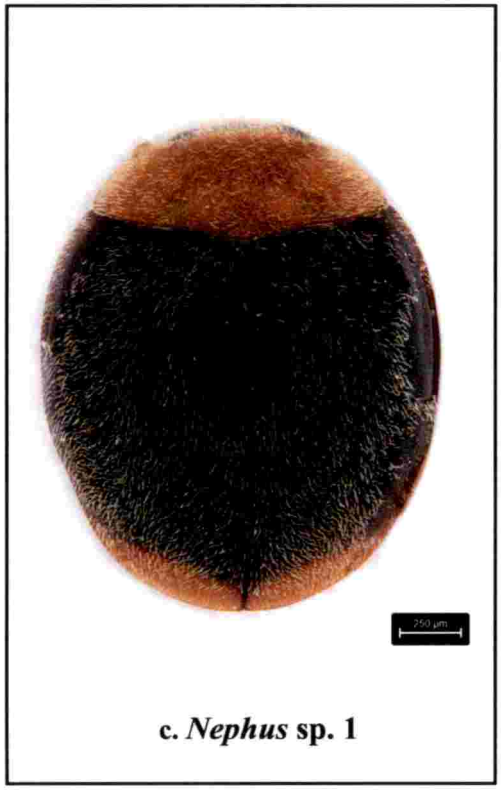
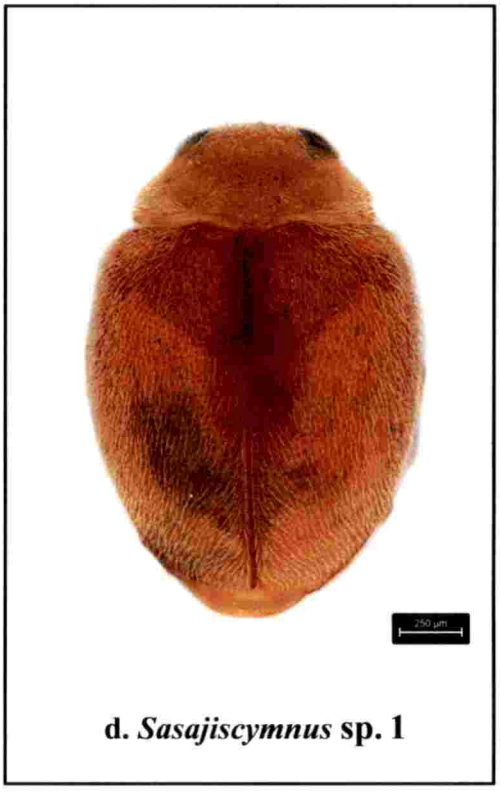
a. *Nephus regularis*

b. *Nephus tagiapatus*



c. *Nephus* sp. 1



d. *Sasajiscymnus* sp. 1

Plate 2. Species of Scymnini

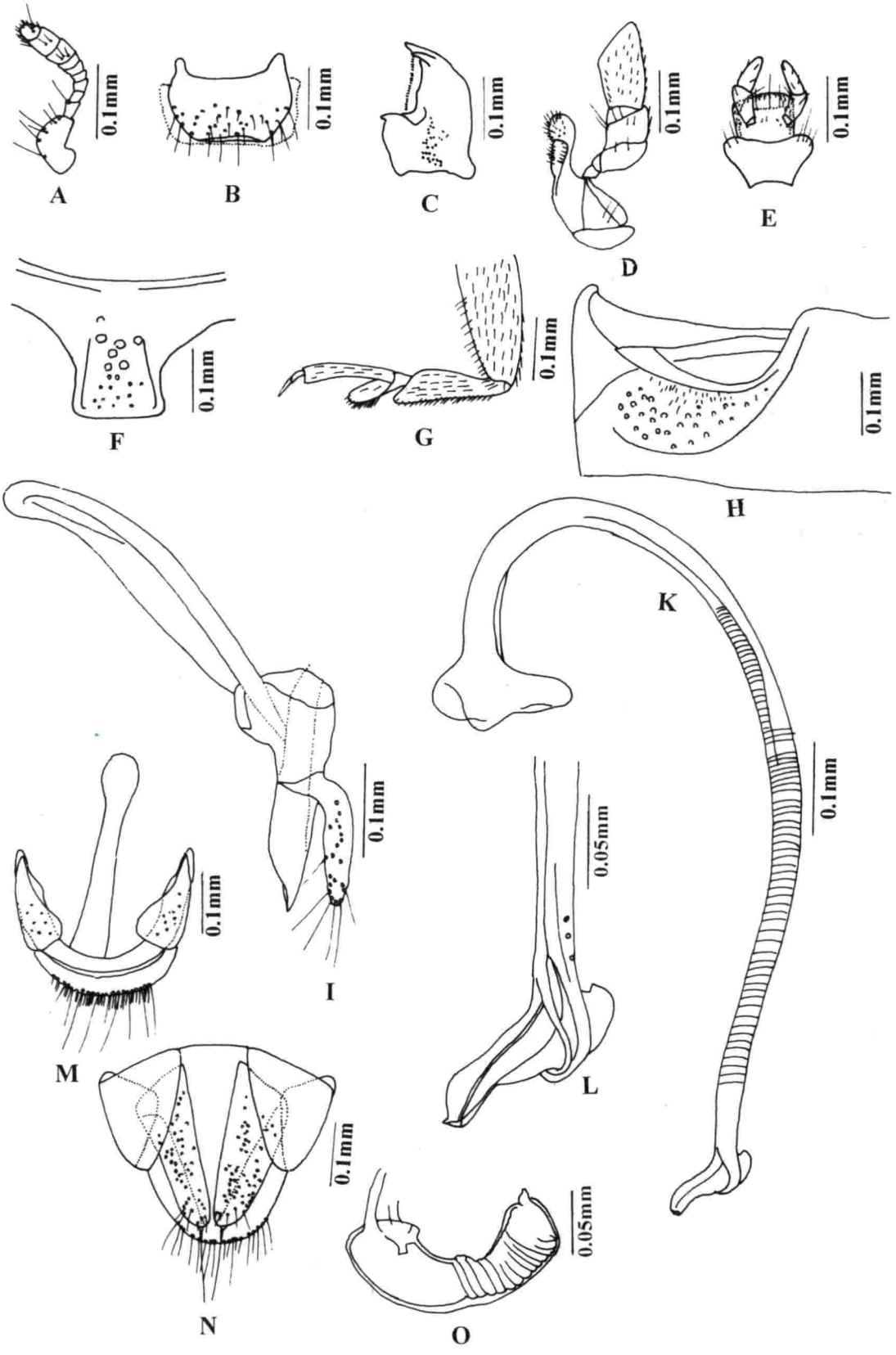


Fig. 9. *Nephus regularis* (Sicard)

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; K. penis; L. penis apex; M. genital segment of male; N. genital segment of female; O. spermatheca

ventrite dark; antenna with 10 antennomeres, scape and pedicel fused, flagellomeres nine; terminal maxillary palpomere nearly parallel sided with apical margin truncate; prosternal process broader with indistinct carina not extending to the anterior end; tarsi trimerous; post coxal line incomplete, parallel to the posterior line of first visible abdominal ventrite upto $4/5^{th}$ of its length and then slightly curved, area enclosed is with evenly distributed punctures.

Male genitalia: Tegmen, with parameres almost equal in length to the penis guide, terminal $1/3^{rd}$ length of penis guide oblique in lateral view; penis sclerotized, basal $1/3^{rd}$ of its length curved and remaining $2/3^{rd}$ almost straight, apex of penis with a distinct process, outer arm of penis capsule broad compared to inner arm.

Female genitalia: Genital plates trigonal, hemisternites triangular; spermatheca slightly curved with a very small projection distally.

Measurements: Male: Total length: 1.72 (1.69 - 1.78) mm, total width: 1.21 (1.18 - 1.31) mm, TL/TW: 1.42 (1.33 - 1.55), PL/PW: 0.58 (0.46 - 0.59), EL/EW: 1.14 (0.96 - 1.22), EW/PW: 1.33 (1.21 - 1.41); **Female:** Total length: 1.74 (1.62 - 1.79) mm, total width: 1.21 (1.1 - 1.23) mm, TL/TW: 1.41 (1.40 - 1.48), PL/PW: 0.49 (0.45 - 0.54), EL/EW: 1.17 (1.1 - 1.19), EW/PW: 1.29 (1.17 - 1.31).

Material: India: Kerala: 1♂, Padannakkad, 20.xii.2015 (VCV); **Karnataka:** 7♂, 6♀, Dharwad, 16.ix.2016 (VCV); 1♀, Raichur, 22.ix.2016 (VCV); **Tamil Nadu:** 1♂, 3♀, Thiruchirappalli, 23.i.2016; 2♂, 3♀, T. Kallupetti, 08.ix.2016 (VCV); 2♂, 3♀, Periyakulam, 09.ix.2016 (VCV).

Prey/Associated host: *Coccidohystrix insolita* (Green) and *Ferrisia virgata* on guava; *Phenacoccus madeirensis* Green on croton; on guava (prey not known).

Remarks: This species is externally similar to another species, *Nephus tagiapatus* in body colour and elytral pattern, but differs the shape of body: *N. regularis* short oval, while *N. tagiapatus* elongated oval. Besides in *N. tagiapatus* the black discolouration on elytra extends gradually towards posterior, whereas black patch is more towards at the base of elytra in *N. regularis*. Penis apex of the two species vary distinctly, *N. regularis* with predominant appendage. One of the morphotype of *N. regularis* without any dark patch on elytra shows external similarity to one of the morphotype of *Scymnus* (*Pullus*) *coccivora* (Plate 4c) and *S.* (*P.*) sp. 6 (Plate

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7a) with uniformly yellowish to orange yellow pronotum and elytra. Among these, *N. regularis* can be separated out with the incomplete post coxal line, while the other two species vary in the arrangement of pubescence, shape of post coxal line and structure of male genitalia.

4. 1. 2. 1. 1. 4. 2. *Nephus tagiapatus* (Kamiya), 1965 (Plate 2b; Fig. 10)

Scymnus (*Nephus*) *tagiapatus* Kamiya, 1965b: 104.

Nephus tagiapatus: Sasaji, 1968: 122; 1971: 130 (desc., ♂ gen. figd.).

Nephus roonwali Kapur, 1967: 163.-Synonymised by Sasaji, 1968: 122.

Diagnosis: This species can be identified by elongate oval body, yellowish or brownish yellow elytra with a dark patch at the base which extends along suture. Tegmen is with slender parameres and penis without any distinct process at the apex.

Description: Body small, elongate oval, weakly convex, dorsum pubescent with yellowish white hairs; head, mouth parts and pronotum yellow to yellowish brown; elytra pale yellowish brown to brownish yellow with dark brown or brownish black area towards the base, extends downwards upto $3/4^{th}$ length, then become pale upto apical region, lateral side of elytra also darker towards anterior and become pale towards posterior region; ventral side yellowish brown and pro-, meso- and metasternum darker; antenna with 10 antennomeres, scape and pedicel fused; terminal maxillary palpomere slightly divergent; prosternal process with indistinct carina not reaching to the anterior end; tarsi trimerous; post coxal line incomplete, parallel to the posterior line of first visible abdominal ventrite, lateral end of the line slightly curved, area enclosed by post coxal line with evenly distributed punctures.

Male genitalia: Tegmen with parameres relatively slender, as long as penis guide, with a few short setae at the apex; penis guide elongate, boat shaped, distal $1/3^{rd}$ of length gradually narrowed towards a pointed apex; penis with basal half curved, preapical region of penis slightly enlarged, capsule of penis with long narrow inner arm and short outer arm; apophysis of ninth abdominal sternite without any dilation at the distal end.

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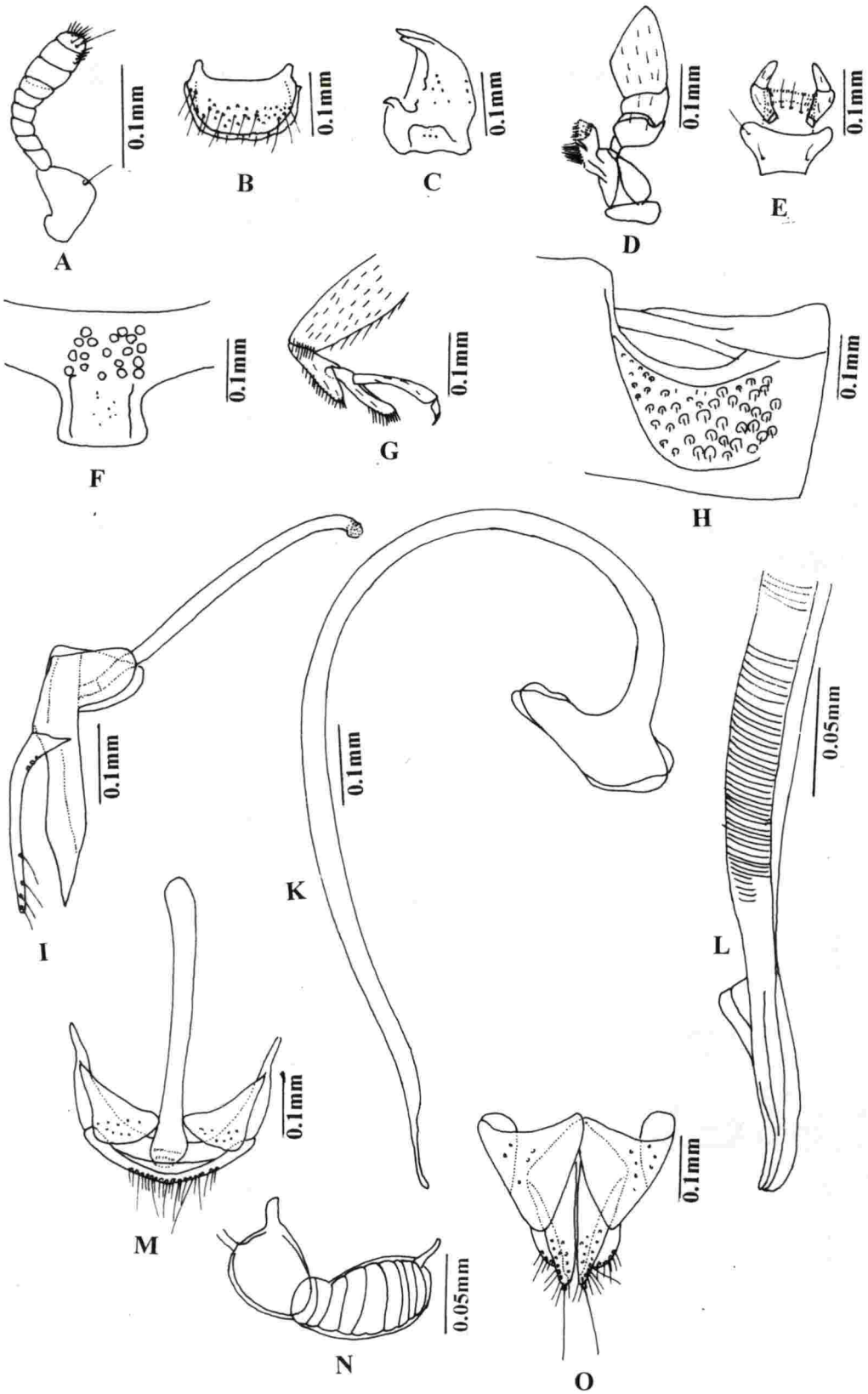

Fig. 10. ***Nephus tagiapatus*** **(Kamiya)**

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; K. penis; L. penis apex; M. genital segment of male; N. genital segment of female; O. spermatheca

Female genitalia: Trigonal genital plates, triangular hemisternites; spermatheca slightly curved constricted in the middle with a very small projection at the distal end.

Measurements: Total length: 1.98 mm, total width: 1.24 mm, TL/TW: 1.59, PL/PW: 0.53, EL/EW: 1.13, EW/PW: 1.27.

Material: India: Tamil Nadu: 1♂, 8♀, Coimbatore, 12.iv.2017 (SB).

Prey/Associated host: *Saccharicoccus sacchari* (Cockerell) on sugarcane.

Remarks: External similarity of *N. tagiapatus* with *N. regularis* is discussed in chapter 4. 1. 2. 1. 1. 4. 1.

4. 1. 2. 1. 1. 4. 3. *Nephus* sp. 1 (Plate 2c; Fig. 11)

Diagnosis: This species is with yellow to orange yellow head and prontum, black or brownish black elytra with orange yellow apical region and stout penis with broad preapical region and a pointed process at the apex.

Description: Body small, broadly oval, strongly convex, densely pubescent with short silvery white hairs; head and pronotum yellow to orange yellow, rarely with a dark coloration at the posterior margin of the pronotum medially; scutellum yellow to brown; elytra brownish black or black with apical region yellow to orange yellow; ventral side flat; yellowish with slightly darker pro-, meso- and metasternum and centre of first abdominal segment; antenna with 10 antennomeres; terminal maxillary palpomere slightly divergent; prosternal process without carina; tarsi trimerous; post coxal line incomplete, parallel to the posterior line of first visible abdominal ventrite upto $4/5^{th}$ of its length and then slightly curved, area enclosed is with evenly distributed fine punctures.

Male genitalia: Tegmen with parameres slender, slightly shorter than penis guide in lateral view; penis guide subtriangular, gradually narrowed to a pointed apex in lateral view; penis stout with curved basal half, preapical portion enlarged, a pointed process at the apex of penis; inner arm of penis capsule longer compared to the broader outer arm; apophysis of ninth sternite broader without any dilation at the distal end.

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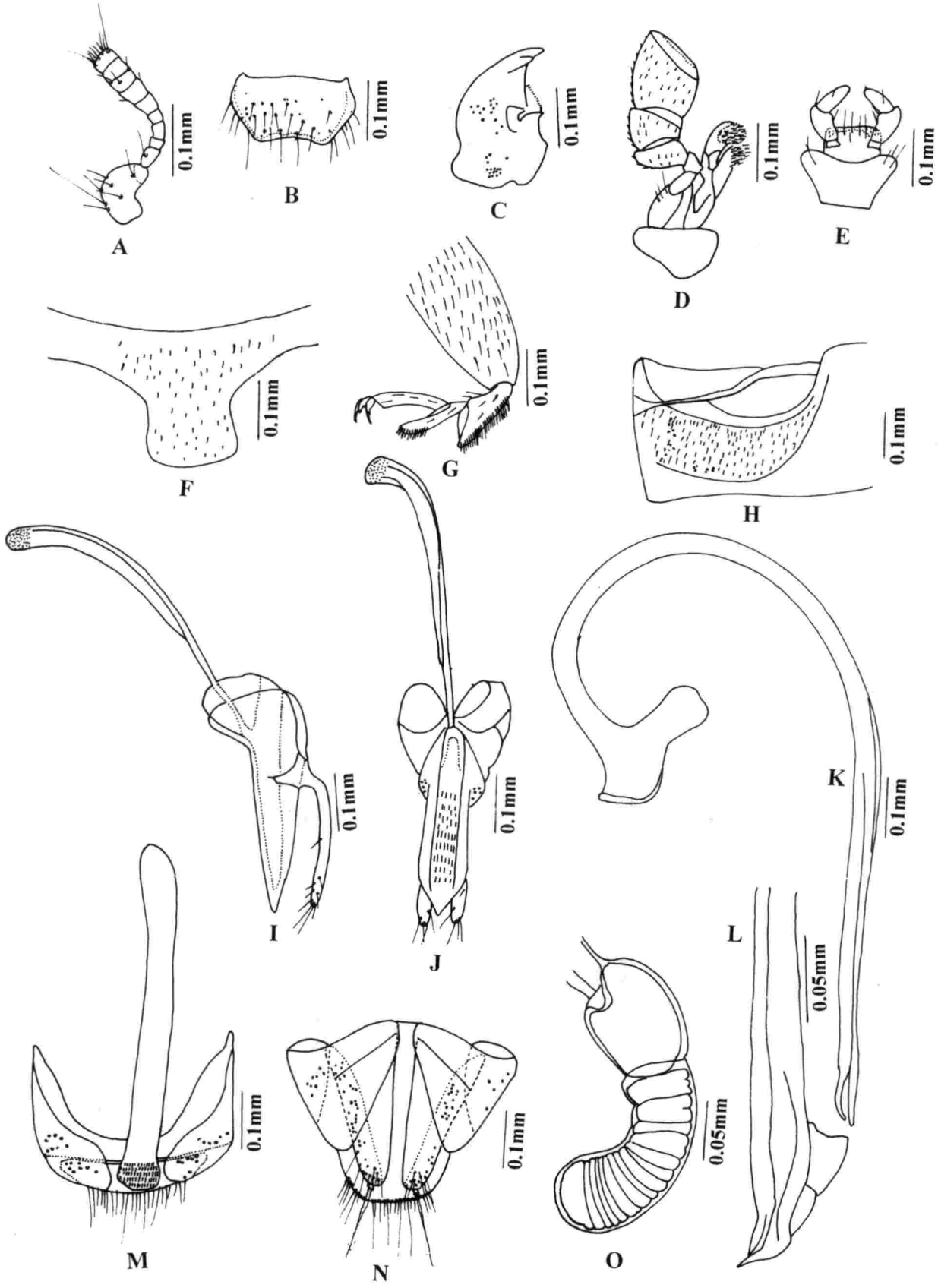

Fig. 11. *Nephus* sp. 1

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex; M. genital segment of male; N. genital segment of female; O. spermatheca

Female genitalia: Hemisternites triangular; spermatheca slightly curved, distal end rounded.

Measurements: Male: Total length: 2.01 (1.92 - 2.16) mm, total width: 1.58 (1.51 - 1.63) mm, TL/TW: 1.27 (1.22 - 1.35), PL/PW: 0.47 (0.40 - 0.51), EL/EW: 0.99 (0.94 - 1.06), EW/PW: 1.32 (1.28 - 1.38); **Female:** Total length: 2.02 (1.76 - 2.21) mm, total width: 1.64 (1.48 - 1.81) mm, TL/TW: 1.22 (1.15 - 1.30), PL/PW: 0.45 (0.39 - 0.50), EL/EW: 0.92 (0.85 - 1.04), EW/PW: 1.32 (1.25 - 1.45).

Material: India: Kerala: 1♂, 2♀, Vadakkenchery, 09.xii.2015 (VCV); 2♀, Chazhur, 03.iii.2016, (VCV); 2♀, Vellanikkara, 08.iii.2016 (VCV); **Karnataka:** 4♂, 4♀, Shivamogga, 05.iv.2016 (VCV); **Tamil Nadu:** 1♂, 1♀, Madurai, 07.ix.2016 (VCV).

Prey/Associated host: *Planococcus citri* (Risso) on annona, cocoa; mealybugs on jack, tamarind.

Remarks: This is probably a new species. *Nephus* sp.1 resembles *Scymnus* (*Pullus*) sp. 7 with yellow/ orange yellow pronotum and black elytra with orange yellow colouration at the tip. However, *N.* sp.1 is more broadly oval with incomplete post coxal line and prosternal process without carina. Male genitalia is also distinctly varied.

4. 1. 2. 1. 1. 5. Genus *Sasajiscymnus* Vandenberg, 2004

Pseudoscymnus Chapin, 1962: 50.

Scymnus (*Scymnus*): H. Kamiya, 1961: 291.

Clitostethus: H. Kamiya, 1961: 279.

Type species: *Scymnus hareja* Weise, 1879, by primary designation.

Sasajiscymnus Vandenberg, 2004: 483 - 484.

Body small, oval, moderately convex, dorsum pubescent; antenna short with nine antennomeres, scape and pedicel relatively larger, extraordinary long setae at the terminal antennomere; prosternum with narrow basisternum and short prosternal process; prosternal carina present; tarsi trimerous; post coxal line of first abdominal ventrite incomplete; parameres distinctly shorter than penis guide.

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Remarks: The similarity of *Sasajiscymnus* with closely related genus *Axinoscymnus* and the characters for differentiating these two genera are discussed in Chapter 4. 1. 2. 1. 1. 1.

4. 1. 2. 1. 1. 5. 1. *Sasajiscymnus* sp. 1 (Plate 2d; Fig. 12)

Diagnosis: This species can be identified by the following characters: presence of antenna with nine antennomeres, distinctly short parameres with a few number of setae at the apical half, relatively broader penis guide and preapical region and slightly enlarged penis.

Description: Body small, oval, moderately convex, dorsum pubescent; head yellowish with pale yellow mouth parts; pronotum pale yellow; elytra yellow; antenna with nine antennomeres, scape and pedicel distinctly broad, terminal four antennomers form the antennal club, distinctly long setae at the terminal antennomere; terminal maxillary palpomere weakly divergent; prosternal carina parallel, giving a rectangle appearance; tarsi trimerous; post coxal lines on first abdominal ventrite incomplete.

Male genitalia: Tegmen with distinctly short parameres with a few numbers of long setae at the apical half; penis guide relatively broader and distinctly longer than parameres; penis curved at the basal 2/3rd region, inner arm of penis capsule longer compared to the outer arm, penis apex slightly enlarged; apophysis of ninth sternite slightly dilated distally.

Measurements: Total length: 1.63 mm, total width: 1.22 mm

Material: India: Kerala: 1♂, 1♀, Avinissery, 11.i.2018 (VCV).

Prey/Associated host: Scales on banana.

Remarks: *Sasajiscymnus* sp. 1 is different from other species of Scymnini with antenna composed of nine antennomeres and distinctly short parameres. This species resembles *S. hareja* (Weise, 1879), but for a minor variation in the penis apex. The colour of elytra also varies. Elytra of *S. hareja* black with a yellowish large spot a little before the middle and reddish yellow apical margin, while elytra entirely yellow for *S.* sp. 1.

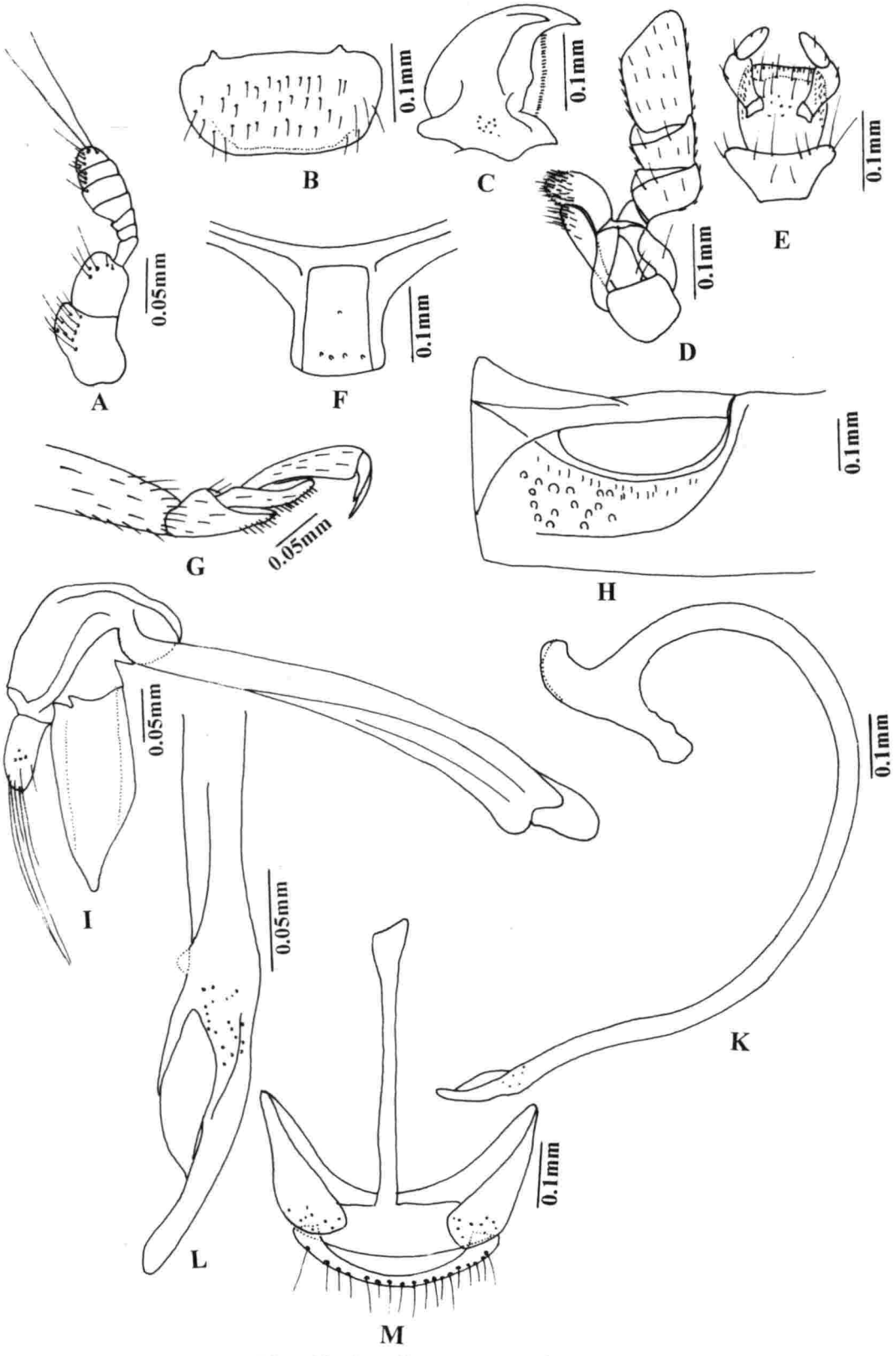

Fig. 12. *Sasajiscymnus* sp.1

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; K. penis; L. penis apex; M. genital segment of male

4. 1. 2. 1. 1. 6. *Scymnus* Kugelann, 1794

Scymnus Kugelann, 1794: 545.-Mulsant, 1846: 219; 1850: 965.-Crotch, 1874: 239. -Korschefsky, 1931: 115.

Type species: *Scymnus nigrinus* Kugelann, 1794: 548, by subsequent designation of Westwood (1838-40).

Body small, short oval to elongate oval, moderately to strongly convex and dorsum pubescent. Head capsule transverse quadrate; antenna with 10 to 11 antennomeres, scape and pedicel not fused; terminal maxillary palpomere always longer than wide, weakly divergent apically or almost parallel; terminal palpomere of labial palp slightly shorter than preapical segment; prosternum T-shaped, weakly excavated in the anterior margin; prosternal process with carina reaching to the anterior margin of prosternum; elytral epipleura very narrow; tarsi trimerous or cryptotetramerous; abdomen with six visible ventrites; post coxal line of first visible abdominal ventrite complete or incomplete.

Remarks: *Scymnus* is distinguished from the related genus *Nephus* by the presences of prosternal carina reaching to the anterior margin and antenna with separate scape and pedicel. This can be separated from other related genus *Horniolus* by the shape of prosternal canina, which is inverted Y-shaped in *Horniolus*.

Key to the species of genus *Scymnus* collected during the study

1 Body elongate oval; antenna with 10 antennomeres; tarsi cryptotetramerous; post coxal line of first abdominal ventrite complete, area enclosed by post coxal line densely and uniformly punctate (Fig. 13H)……..…..***Scymnus* (*Neopullus*)** Sasaji……..……..…2

_ Body oval; antenna with 10 or 11 antennomeres; tarsi trimerous or cryptotetramerous; post coxal line of first abdominal ventrite complete or incomplete, punctuation in the area enclosed by post coxal line is not uniformly punctate.....3

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2(1) Tegmen with parameres shorter than penis guide (Fig. 13I)..... .....***Scymnus* (*Neopullus*) *hoffmanni*** Weise

_ Tegmen with parameres almost equal to penis guide (Fig. 14I)..... .....***Scymnus* (*Neopullus*) sp.1**

3(1) Antenna with 11 antennomeres; tarsi cryptotetramerous; post coxal line of first abdominal ventrite complete or incomplete.....4

_ Antenna with 10 antennomeres; tarsi trimerous; post coxal line of first abdominal ventrite complete 18

4(3) Post coxal line of first abdominal ventrite incomplete (Fig. 30H)..... .....***Scymnus* (*Scymnus*)** Kugelann

_ Post coxal line of first abdominal ventrite complete (Fig. 15H)..... .....***Scymnus* (*Pullus*)** Mulsant.....5

5(4) Elytra uniformly brownish yellow or yellowish brown without any markings; penis guide broad (Fig. 28J), with a prominent dorsal keel (Fig. 28I).....***Scymnus* (*Pullus*) sp. 9**

_ Elytral pattern varied; penis guide not broad, without a prominent dorsal keel.....6

6(5) Black and orange coloured elytra; apex of penis simple..... 7

_ Colour pattern of elytra and pronotum varied; apex of penis complex with or without any appendage.....8

7(6) Elytra black with orange yellow apex; parameres as long as penis guide; penis uniform throughout its length with a narrow apex (Fig. 26K).....***Scymnus* (*Pullus*) sp. 7**

_ Elytra black with apical 1/4th yellow; parameres longer than penis guide; preapical region of penis broader (Fig. 27K)..... .....***Scymnus* (*Pullus*) sp. 8**

8(6) Apex of penis without any appendage.....9

_ Apex of penis with prominent thread like/finger like appendage 10

9(8) Elytra pale golden yellow to yellowish brown often with dark brown patches and spots; penis guide longer than parameres; penis capsule with a broad outer process; apex of penis straight (Fig. 16K)..... .....***Scymnus* (*Pullus*) *coccivora*** Ayyar

_ Elytra uniformly yellowish without any markings; penis guide shorter than parameres; penis capsule with a short outer arm; apex of penis bent inwards at an obtuse angle (Fig. 25K)..... ***Scymnus* (*Pullus*) sp. 6**

10(8) Apical region of penis with short and finger like appendage..... 11

_ Apical region of penis with long and thread like appendage..... 13

11(10) Penis with a finger like process at the apex (Fig. 21L)..... ..... ***Scymnus* (*Pullus*) sp. 2**

_ Penis with finger like appendage in subapical position..... 12

12(11) Elytra black with two pairs of orange yellow subquadrate patch; penis with a 'bud' like process towards middle on the inner margin, hook like process in the subapical position (Fig. 17K)..... .....***Scymnus* (*Pullus*) *latemaculatus*** Motschulsky

_ Elytra uniformly yellow or black with yellow apical region; penis without any process along its length, penis apex slightly broader with a

very short, blunt process in the subapical region (Fig. 19K)..... .....***Scymnus* (*Pullus*) *utilis*** Hoang

13(10) Thread like appendage at penis sub apical in position (Fig. 23K).....14

_ Thread like appendage at penis apical in position (Fig. 18K).....15

14(13) Elytra dark brown to black with reddish brown lateral and apical margin; parameres longer than penis guide with setae on almost entire length (Fig. 23J)..... ***Scymnus* (*Pullus*) sp. 4**

_ Elytra entirely orange yellow; parameres shorter than penis guide with setae on distal 1/3rd position (Fig. 24J)..... ***Scymnus* (*Pullus*) sp. 5**

15(13) Elytra reddish brown, sometimes with a darker area at the base near the suture; penis guide half length of parameres (Fig. 15I)..... .....***Scymnus* (*Pullus*) *castaneus*** Sicard

_ Elytral pattern vary; penis guide 2/3rd of the length of parameres (Fig. 18I).....16

16(15) Pronotum black with ornage yellow patches on lateral and anterior margin; elytra with apical 1/4th region orange yellow..... .....***Scymnus* (*Pullus*) *pyrocheilus*** Mulsant

_ Elytra and pronotum uniformly coloured without any patches; length of appendage on penis apex vary.....17

17(16) Pronotum and elytra reddish brown; length of appendage of penis apex 0.45mm (Fig. 20L)..... ***Scymnus* (*Pullus*) sp. 1**

_ Pronotum and elytra blackish brown with relatively lighter shade towards the apical and lateral margins, length of appendage of penis apex 0.35mm (Fig. 22L)..... ***Scymnus* (*Pullus*) sp. 3**

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18(3) Pronotum either yellow or yellow with black colouration at the posterior middle portion; elytra black with a very narrow yellowish discolouration at the apical margin; parameres shorter than penis guide (Fig. 31I); penis expanded at the apex with a prominent short pointed tip..... ***Scymnus saciformis*** Motschulsky

_ Pronotum yellow; elytra black with apical 1/3rd yellow; parameres almost equal to penis guide (Fig. 32I); penis apex expanded with rounded outline..... ***Scymnus* sp. 1**

Subgenus *Scymnus* (*Neopullus*) Sasaji, 1971

Scymnus (*Neopullus*) Sasaji, 1971: 177. Type species: *Scymnus hoffmanni* Weise, 1879, by original designation.

Scymnus (*Caledonus*) Bielawski, 1973: 397. Type species *Scymnus angusticollis* Fauvel, 1903, by original designation. Synonymised by Yu & Pang, 1992: 39.

Body usually elongate oval, moderately convex, densely pubescent; antenna with 10 antennomeres not forming a distinct club; labrum transverse; mandible bifid apically; terminal maxillary palpomere weakly divergent; labial palp with three palpomeres, terminal one shorter than the preapical one; prosternum with distinct carina; tarsi cryptotetramerous; post coxal line of first abdominal ventrite complete reaching the base of abdominal ventrite, area enclosed by the line densely and uniformly punctate.

Remarks: Subgenus *Neopullus* of *Scymnus* is easily separated from *Scymnus* (*Scymnus*) by antenna with 10 antennomeres and dense and uniform punctuation on the area enclosed by the post coxal line on abdominal ventrite.

4. 1. 2. 1. 1. 6. 1. *Scymnus* (*Neopullus*) *hoffmanni* Weise, 1879 (Plate 3a; Fig. 13)

Scymnus hoffmanni Weise, 1879: 152.

Pullus hoffmanni: Ohta, 1929: 9.

Scymnus (Nephus) hoffmanni: Kurisaki, 1923: 16.

Scymnus (Pullus) hoffmanni: Korschefsky, 1931: 127 (cat.).

Scymnus (Neopullus) hoffmanni: Sasaji, 1971: 178.- Chen *et al.*, 2014: 318.

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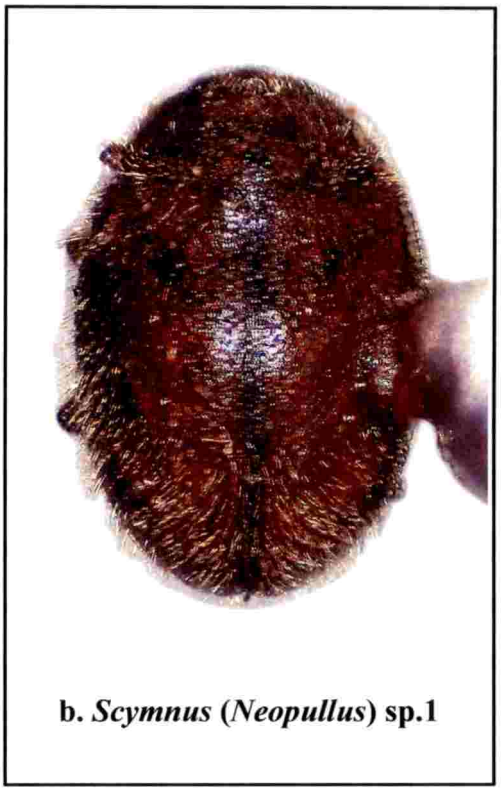
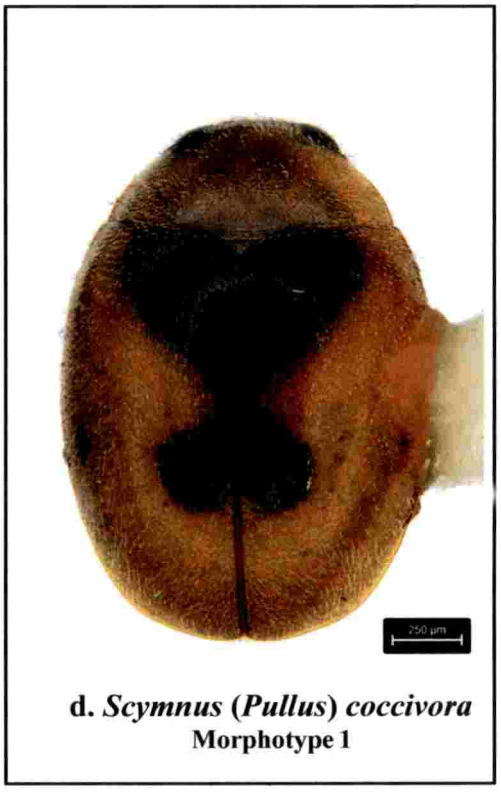
a. *Scymnus* (*Neopullus*) *hoffmanni*



b. *Scymnus* (*Neopullus*) sp.1

c. *Scymnus* (*Pullus*) *castaneus*



d. *Scymnus* (*Pullus*) *coccivora*
Morphotype 1

Plate 3. Species of Scymnini

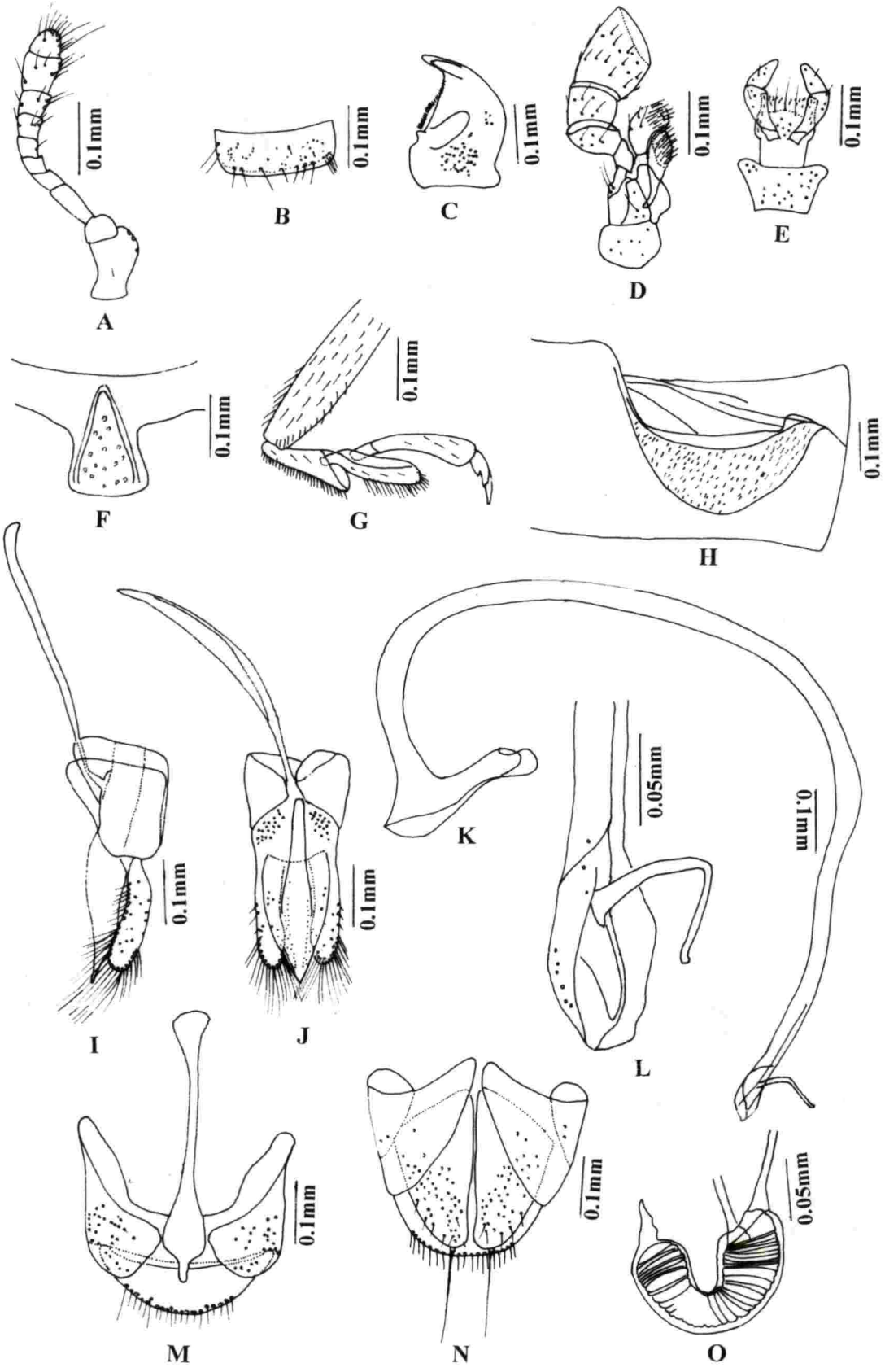


Fig. 13. *Scymnus* (*Neopullus*) *hoffmanni* Weise

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex; M. genital segment of male; N. genital segment of female; O. spermatheca

Diagnosis: This species can be identified by the densely pubescent dorsum, area enclosed by post coxal lines very densely and uniformly punctate, tegmen with parameres shorter than penis guide and penis apex swollen with a thread like appendage.

Description: Body small, elongate oval, moderately convex, dorsum densely pubescent with yellowish white hairs; head and mouth parts light brown; pronotum brown with lateral margins lighter; elytra brown to dark brown with posterior ends relatively lighter; ventral side light with meso- and metasternum and anterior part of abdomen darker; antenna with 10 antennomeres; terminal maxillary palpomere weakly divergent; prosternal carina strongly divergent posteriorly; tarsi cryptotetramerous; post coxal line complete, broadly curved, reaching basal margin of first abdominal ventrite, area enclosed by lines very densely and uniformly punctate.

Male genitalia: Tegmen stout; parameres with medium dense hairs; penis guide widest at the base, gradually narrowed towards a pointed apex, longer than parameres; penis relatively stout, basal $3/4^{th}$ curved, penis apex swollen with short thread like appendage, penis capsule with long inner arm and short outer arm; apophysis of the ninth sternite expanded distally.

Female genitalia: Genital plates slightly tetragonal, hemisternite triangular; spermatheca curved constricted in the middle with a distict projection at the distal end.

Measurements: Total length: 2.00 (1.86 -2.14) mm, total width: 1.37 (1.29 - 1.47) mm, TL/TW: 1.45 (1.28 - 1.65), PL/PW: 0.50 (0.42 - 0.55), EL/EW: 1.22 (1.06 - 1.29), EW/PW: 1.28 (1.18 - 1.38).

Material: India: Kerala: 1♂, 6♀, Vellanikkara, 07.i.2016 (VCV).

Remarks: Illustrations and descriptions of male genitalia of this species match with the descriptions and illustrations of male genitalia *S.* (*N.*) *hoffmanni* by Sasaji (1971) and Chen *et al.* (2014). The specimen collected during this study deviates from the common colour pattern of elytra of *S.* (*N.*) *hoffmanni* i.e. reddish brown with basal, sutural and lateral margins continuously dark. But specimens with entirely black elytra is also reported.

4. 1. 2. 1. 1. 6. 2. *Scymnus* (*Neopullus*) sp.1 (Plate 3b; Fig. 14)

Diagnosis: This species can be identified by densely pubescent dorsum, area enclosed by post coxal lines very densely and uniformly punctate, tegmen with parameres almost equal to penis guide and penis apex swollen with a thread like appendage.

Diagnostic characters: Body small, elongate oval, moderately convex, dorsum pubescent; head and mouth parts light brown; pronotum reddish brown; elytra reddish brown with a black patch along the suture; ventral side blackish brown; antenna with 10 antennomeres; last segment of maxillary palp weakly divergent; prosternal carina divergent posteriorly; tarsi cryptotetramerous; post coxal line complete, broadly curved, reaching basal margin of first abdominal ventrite, area enclosed by lines very densely and uniformly punctate.

Male genitalia: Parameres with dense hairs; penis guide widest at the base, gradually narrowed towards a blunt tip, slightly shorter than parameres; penis relatively stout, basal 2/3rd curved, penis apex swollen with a thread like appendage, penis capsule with long inner arm and short outer arm.

Measurements: Total length: 2.01 mm, total width: 1.43 mm.

Material: India: Kerala: 1♂, Kumarakom, 14.iii.2016 (VCV).

Prey/Associated host: Not known.

Remarks: This species is very much similar to *S.* (*N.*) *yamato*, but slight variation in the penis apex. This species resembles *S.* (*N.*) *hoffmanni*, but differs with a relatively narrower prosternal process and shorter penis guide than parameres. Elytral pattern gives this species an external similarity to *S.* (*S.*) *nubilus*.

Subgenus *Scymnus* (*Pullus*) Mulsant, 1846

Scymnus (*Pullus*) Mulsant, 1846: 241.

Pullus: Motschulsky, 1866: 426. Type species: *Coccinella subvillosa* Goeze, 1777: 247, by subsequent designation of Korschefsky, 1931.

Body small, oval, convex, dorsum densely pubescent; antenna with 11 antennomeres, terminal three antennomeres forming club; mandibles bifid apically;

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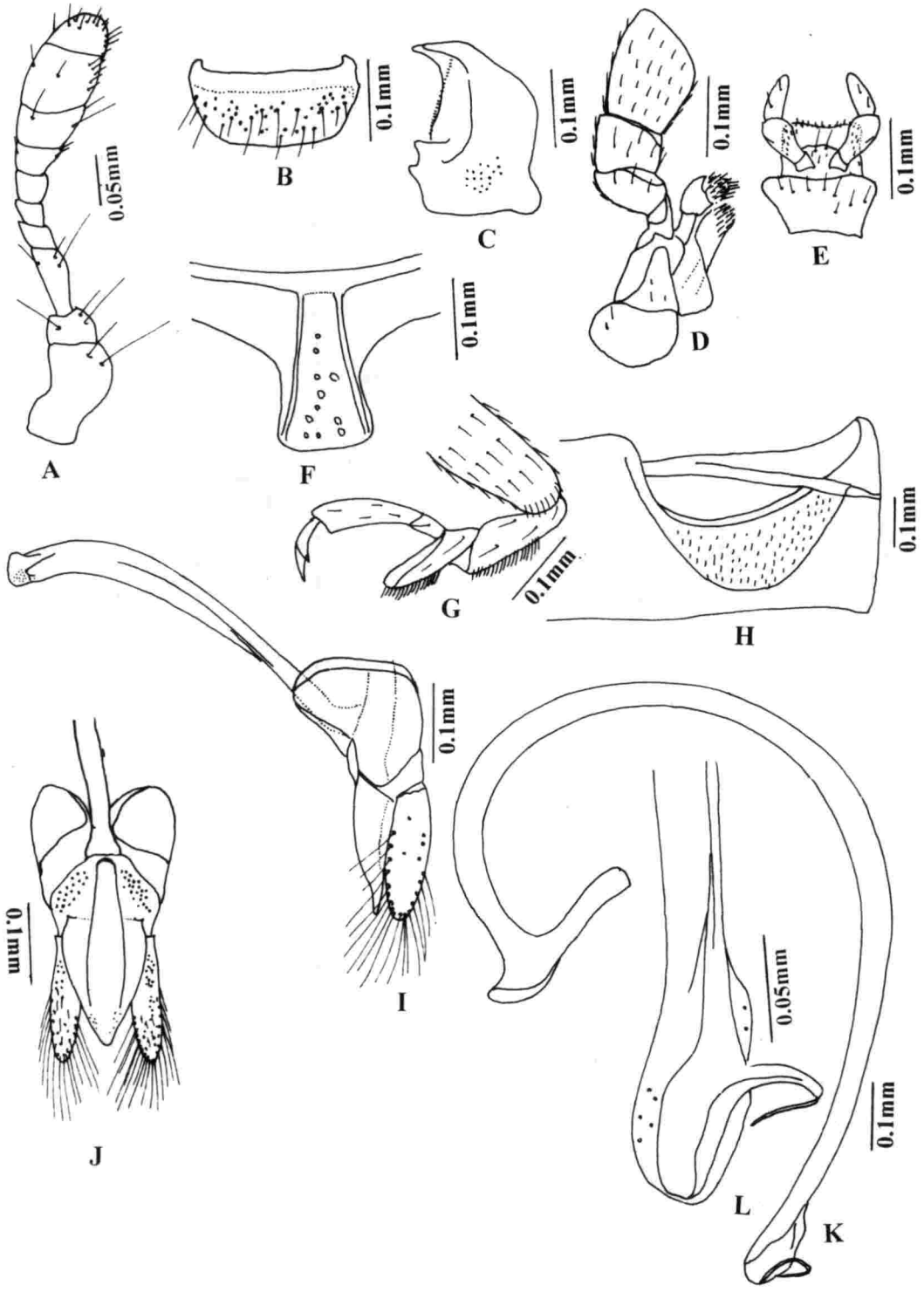

Fig. 14. ***Scymnus*** **(*Neopullus*) sp. 1**

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex

terminal maxillary palpomere weakly divergent; labial palpomere three, terminal palpomere shorter than the preapical one; prosternal carina distinct, always reaching the anterior margin of prosternum; tarsi cryptotetramerous; post coxal line of first abdominal ventrite complete, recurved apically, reaching the base of abdominal ventrite.

Remarks: *Scymnus* (*Pullus*) is closely related to *Scymnus* (*Scymnus)*, but can be separated by the presence of complete post coxal line on the first abdominal ventrite.

4. 1. 2. 1. 1. 6. 3. *Scymnus (Pullus) castaneus* Sicard, 1929 (Plate 3c; Fig. 15)

Scymnus (Pullus) castaneus Sicard, 1929: 180.

Scymnus (Pullus) castaneus: Korschefsky, 1931: 142 (cat.).

Diagnosis: This species is distinguished by reddish brown elytra and male genitalia with penis guide half the length of parameres and penis apex with long thread like appendage.

Description: Body slightly oval, convex, densely pubescent with white hairs; head reddish brown to brown; mouth parts dark brown; pronotum reddish brown to dark brown; scutellum dark brown; elytra reddish brown, sometimes with darker area near the suture medially; ventral side reddish brown with darker meso-, metasternum and anterior part of first abdominal ventrite; legs yellowish to reddish brown; antenna with 11 antennomeres, last three antennomeres forming the antennal club; last segment of maxillary palp weakly divergent; prosternal carina present and divergent posteriorly; tarsi cryptotetramerous; post coxal line complete, broadly curved, boat shaped, in some members lines appears broken on lateral margin and appear as incomplete, area enclosed by lines coarsely punctate, posterior part of inner margin smooth.

Male genitalia: Tegmen moderately stout; parameres with long dense hairs; penis guide shorter than parameres reaching only half the length of parameres in lateral view, penis guide widest at the base, narrowed towards apex from half its length in ventral view; penis strongly curved at the basal 2/3rd length, penis apex with long

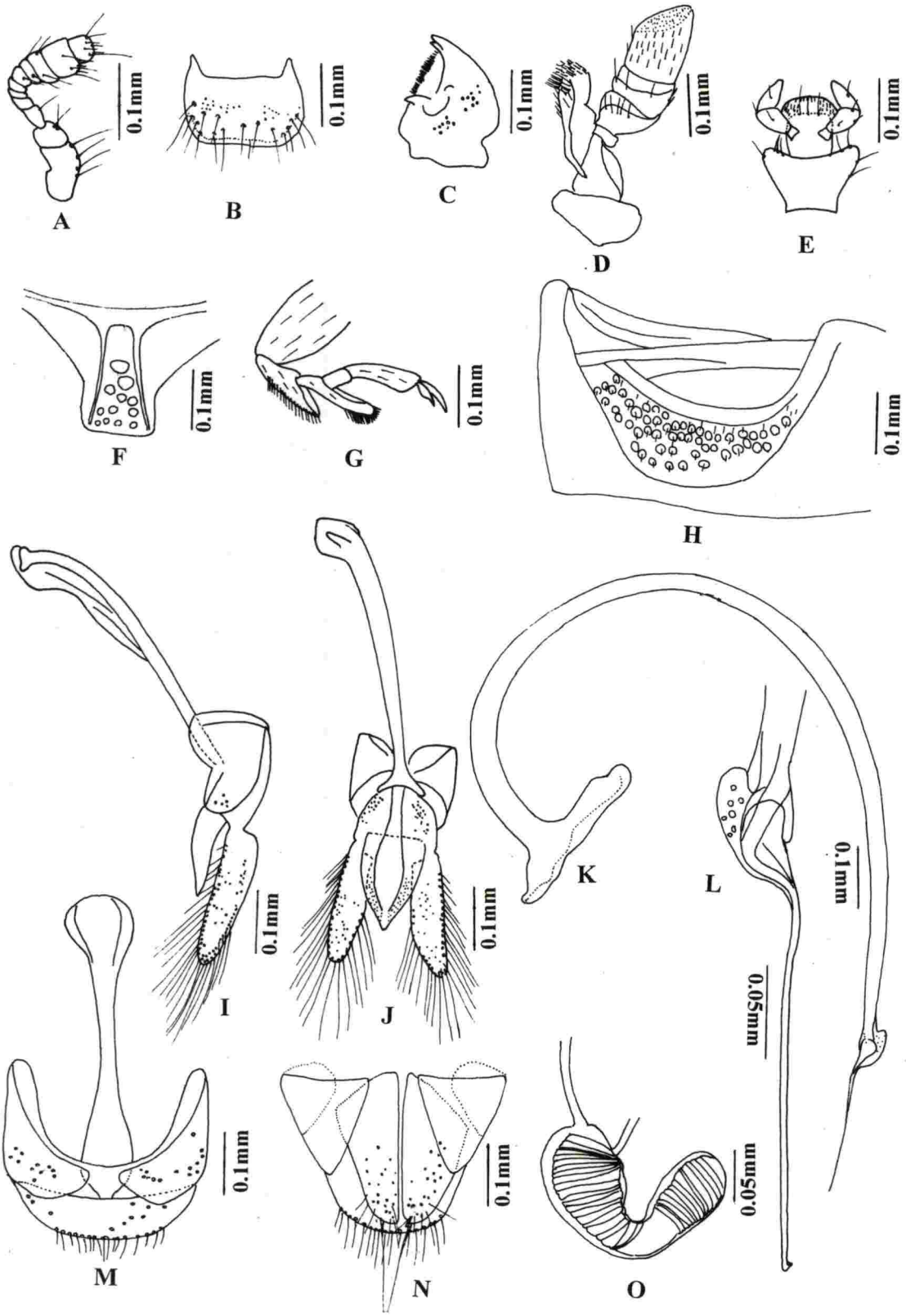

Fig. 15. ***Scymnus* (*Pullus*) *castaneus* Sicard**

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex; M. genital segment of male; N. genital segment of female; O. spermatheca

thread like appendage, penis capsule with long inner arm and short outer arm; apophysis of the ninth sternite expanded distally.

Female genitalia: Genital plates trigonal; hemisternites triangular; spermatheca broadly V-shaped.

Measurements: Male: Total length: 1.83 (1.75 - 1.91) mm, total width: 1.31 (1.15 - 1.42) mm, TL/TW: 1.34 (1 -1.45), PL/PW: 0.51 (0.51 - 0.52), EL/EW:1.00 (0.97 - 1.11), EW/PW: 1.29 (1.25 - 1.33); **Female:** Total length: 1.95 (1.91 - 2.07) mm, total width: 1.46 (1.43 - 1.52) mm, TL/TW: 1.39 (1.28 - 1.52), PL/PW: 0.53 (0.49 - 0.56), EL/EW: 1.04 (0.97 - 1.11), EW/PW: 1.30 (1.26 - 1.32).

Material: India: Karnataka: 2♂, 1♀, Dharwad, 16.ix.2016 (VCV); **Tamil Nadu:** 2♂, 1♀, Tiruchirappalli, 24.i.2016 (VCV); 4♂, 7♀, Madathukulam, 12.iv.2016 (VCV).

Prey/Associated host: *Aphis gossypii* on guava; on castor (prey not known).

Remarks: *Scymnus* (*Pullus*) *castaneus* resembles with *S.* (*P.*) *pyrocheilus*, *S.* (*P.*) sp. 1 and *S.* (*P.*) sp. 3 with a long appendage at the penis apex. But this species is different from other three with shorter paramers with respect to penis guide compared to other three species.

4. 1. 2. 1. 1. 6. 4. *Scymnus* (*Pullus*) *coccivora* Ayyar, 1925 (Plate 3d, 4a, 4b; Fig. 16)

Scymnus coccivora Ayyar, 1925: 491.

Scymnus (Pullus) coccivora Korschefsky, 1931: 142.

Pullus coccidivora Chelliah, 1965: 165 (♂ genitalia figd.).

Scymnus (Pullus) elegans Sicard, 1929: 182. -Korschefsky, 1931: 142 (cat.).

Scymnus (Pullus) elegans var. *clathratus* Sicard, 1929: 182.

Diagnosis: This species can be identified by golden yellow to yellowish brown elytra, usually with dark brown hour glass shaped markings along the elytral suture and strongly expanded penis capsule.

Description: Body small, slightly oval, strongly convex and dorsum pubescent; head yellow to yellowish brown with yellowish brown mouth parts; pronotum and scutellum yellowish brown; three morphotypes identified based on elytral pattern:

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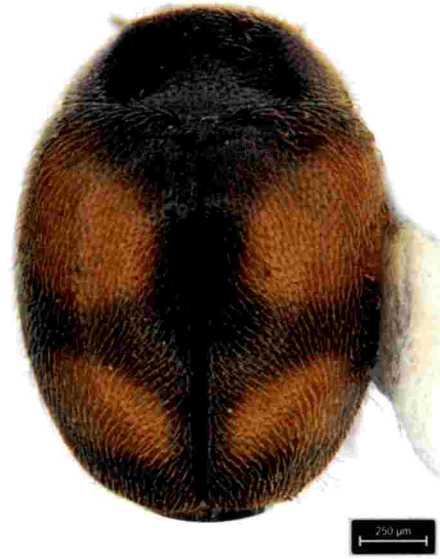
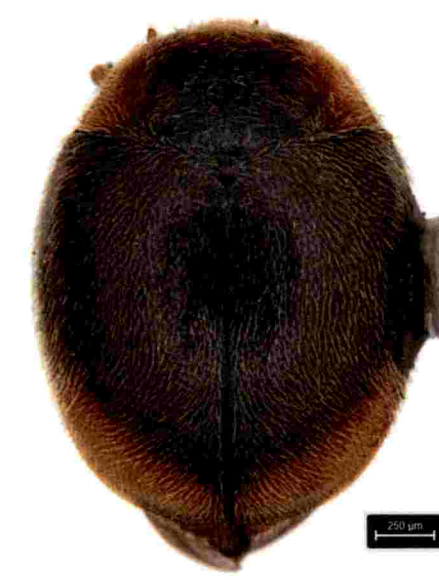
a. *Scymnus* (*Pullus*) *coccivora*
Morphotype 2

b. *Scymnus* (*Pullus*) *coccivora*
Morphotype 3



c. *Scymnus* (*Pullus*) *latemaculatus*



d. *Scymnus* (*Pullus*) *pyrocheilus*

Plate 4. Species of Scymnini

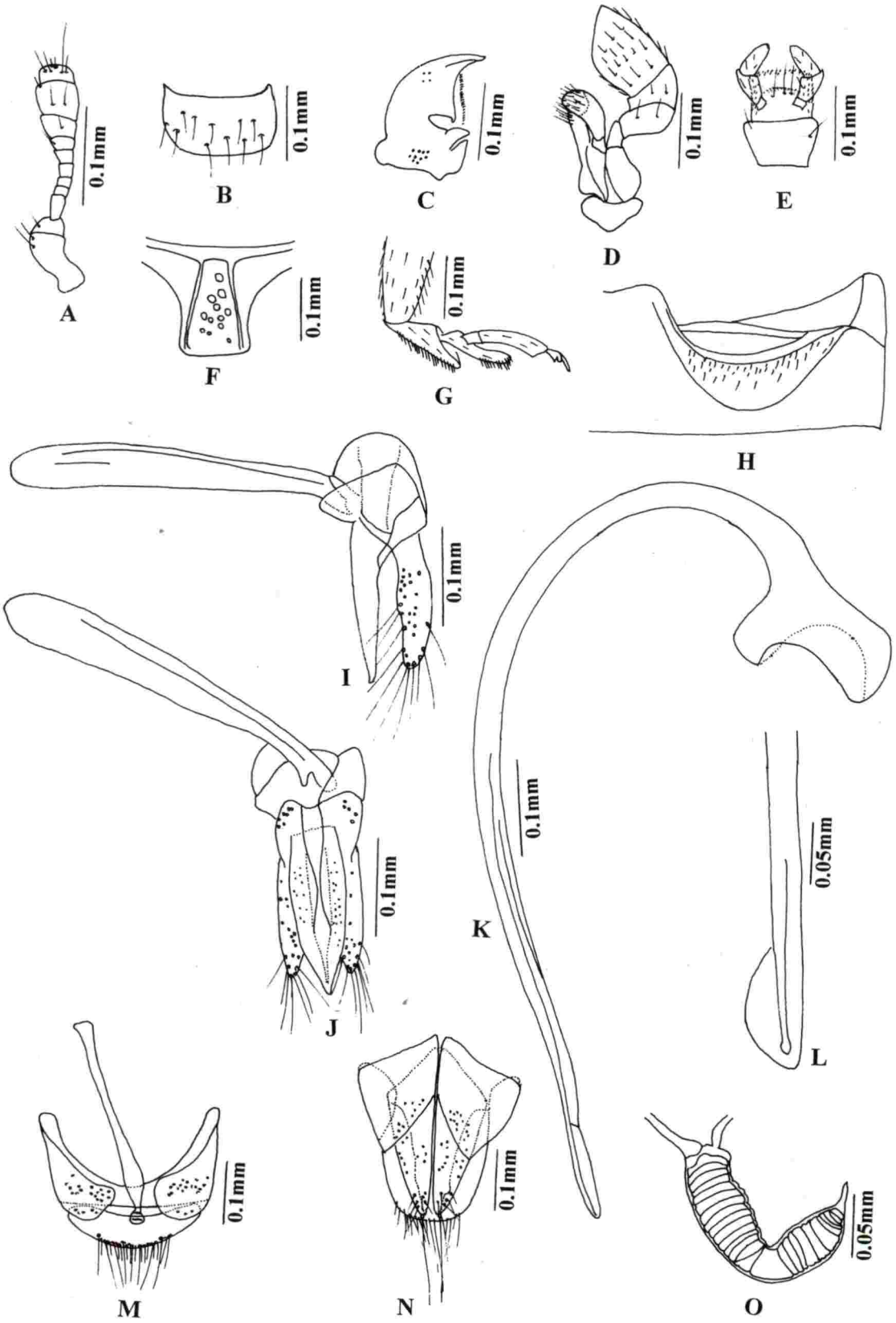


Fig. 16. *Scymnus* (*Pullus*) *coccivora* Ayyar

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex; M. genital segment of male; N. genital segment of female; O. spermatheca

i. elytra pale golden yellow to yellowish brown with dark brown hour glass shaped markings along the elytral suture on the basal half, one circular small dark brown spot on the lateral side of elytra, ii. elytra only with markings along the suture, not with lateral circular spot, iii. elytra uniformly yellowish brown completely devoid of markings; ventral side yellowish brown with dark brown pro-, meso- and metasternum; legs yellow; antenna with 11 antennomeres, prosternal carina present and slightly broader towards posterior; tarsi cryptotetramerous; post coxal line complete, deeply curved, area adjacent to post coxal line smooth.

Male genitalia: Tegmen with penis guide longer than parameres, apex of parameres with medium long hairs; penis curved, penis capsule with a broader outer process, apex of penis narrow with a membranous part covering the terminal end.

Female genitalia: Hemisternites triangular; spermatheca is slightly curved with a projection on the distal end.

Measurements: Male: Total length: 1.56 (1.53 - 1.60) mm, total width: 1.13 (1.05 - 1.22) mm, TL/TW: 1.39 (1.33 - 1.42), PL/PW: 0.49 (0.46-0.56), EL/EW: 1.01 (0.95 - 1.12), EW/PW: 1.26 (1.21 - 1.31); **Female:** Total length: 1.62 (1.54 - 1.76) mm, total width: 1.27 (1.15 - 1.36) mm, TL/TW: 1.35 (1.29 - 1.43), PL/PW: 0.53 (0.47 - 0.56) EL/EW: 1.06 (0.95 - 1.12) EW/PW: 1.29 (1.26 - 1.31).

Material: India: Kerala: 2♂, 3♀, Vadakarapathy, 02.xii.2015 (VCV); 1♂, Tavanur, 12.xii.2015 (VCV); 2♀, 20.xii.2015, Padannakkad (VCV); 8♂, 12♀, Mannuthy, 05.ii.2016 (VCV); 1♀, Perumbavoor, 25.ii.2016 (VCV); 5♂, 8♀, Vellanikkara, 02.iii.2016, 26.iii.2016, 14.iv.2016 (VCV); 2♂, 2♀, Kayamkulam, 09.iii.2016 (VCV); 1♂, 2♀, Kumarakom, 14.iii.2016 (VCV); **Karnataka:** 2♀, Bengaluru, 26.xii.2015 (VCV); 2♂, 3♀, Shivamogga, 05.iv.2016 (VCV); 1♀, Dharwad, 16.ix.2016 (VCV); 2♀, Raichur, 23.ix.2016 (VCV); **Tamil Nadu:** 3♀, Coimbatore, 14.viii.2015 (VCV); 1♂, 1♀, Tiruchirappalli, 24.i.2016 (VCV); 1♂, 2♀, Madathukulam, 12.iv.2016 (VCV); 2♂, Madurai, 07.ix.2016 (VCV); 2♂, 3♀, Periyakulam, 09.ix.2016 (VCV).

Prey/Associated host: *Coccidohystrix insolita* on brinjal; *Ferrisia virgata* on *Abutilon*, guava, *Jatropha*; *Paracoccus marginatus* on papaya, tapioca; *Phenacoccus solenopsis* Tinsley on *Abutilon*; *Planococcus citri* on croton;

Pseudococcus longispinus (Targioni and Tozzetti) on bottle palm; mealybug on guava, *Mussaenda*.

Remarks: This is a common species associated with mealybugs. This species is easily distinguished by the elytral pattern. But one of the morphotype of *S.* (*P.*) *coccivora*, which is uniformly yellowish brown without any markings on elytra shows external similarity to one of the morphotype of *Nephus regularis*, *S.* (*P.*) sp. 6 and *S.* (*P.*) 9. Distinguishing features of *N. regularis* and *S.* (*P.*) *coccivora* have already been discussed in chapter 4.1.2.1.1.4.1. Penis guide of male genitalia is longer than parameres in *S.* (*P.*) *coccivora*, whereas it is shorter than parameres in *S.* (*P.*) sp.6 and apex of penis also vary distinctly. Presence broader penis guide with a dorsal keel separates *S.* (*P.*) sp. 9 from *S.* (*P.*) *coccivora*.

4. 1. 2. 1. 1. 6. 5. *Scymnus* (*Pullus*) *latemaculatus* Motschulsky, 1858 (Plate 4c; Fig.17)

Scymnus latemaculatus Motschulsky, 1858: 121. -Korschefsky, 1931: 144 (cat., as synonym of *S. quadrillum*).-Iablokoff-Khnzorian, 1972: 167.

Scymnus quadrillum auctt.: Kapur, 1942: 61.-Chelliah, 1965: 166 (♂ genitalia figd.). -Iablokoff-Khnzorian, 1972: 167. -Yang, 1978b: 107 (redesc.).

Nephus quadrillum: Iablokoff-Khnzorian, 1972: 167 (synonymised).

Scymnus transversoplagiatus Motschulsky, 1858: 120.-Crotch, 1874: 253. -Korschefsky, 1931: 144 (cat.). -Iablokoff-Khnzorian, 1972: 167.

Pullus taiwanus Ohta, 1929: 6. -Korschefsky, 1931: 145 (cat.). -Yang, 1978b: 107 (syn.).

Scymnus (*Pullus*) *taiwanus:* Kamiya, 1965a: 75. -Pang & Gordon, 1986: 173.

Diagnosis: This species is distinguished by the following characters of male genitalia: penis guide with a deep emargination on both sides towards terminal end in ventral view, penis with short appendage at the preapical region, ring like annulations and a bud like process at the apical 1/3rd portion and penis capsule funnel/trumpet shaped.

Description: Body slightly oval; moderately convex, dorsum pubescent with silvery white hairs; head yellowish brown to light brown; mouth parts light brown

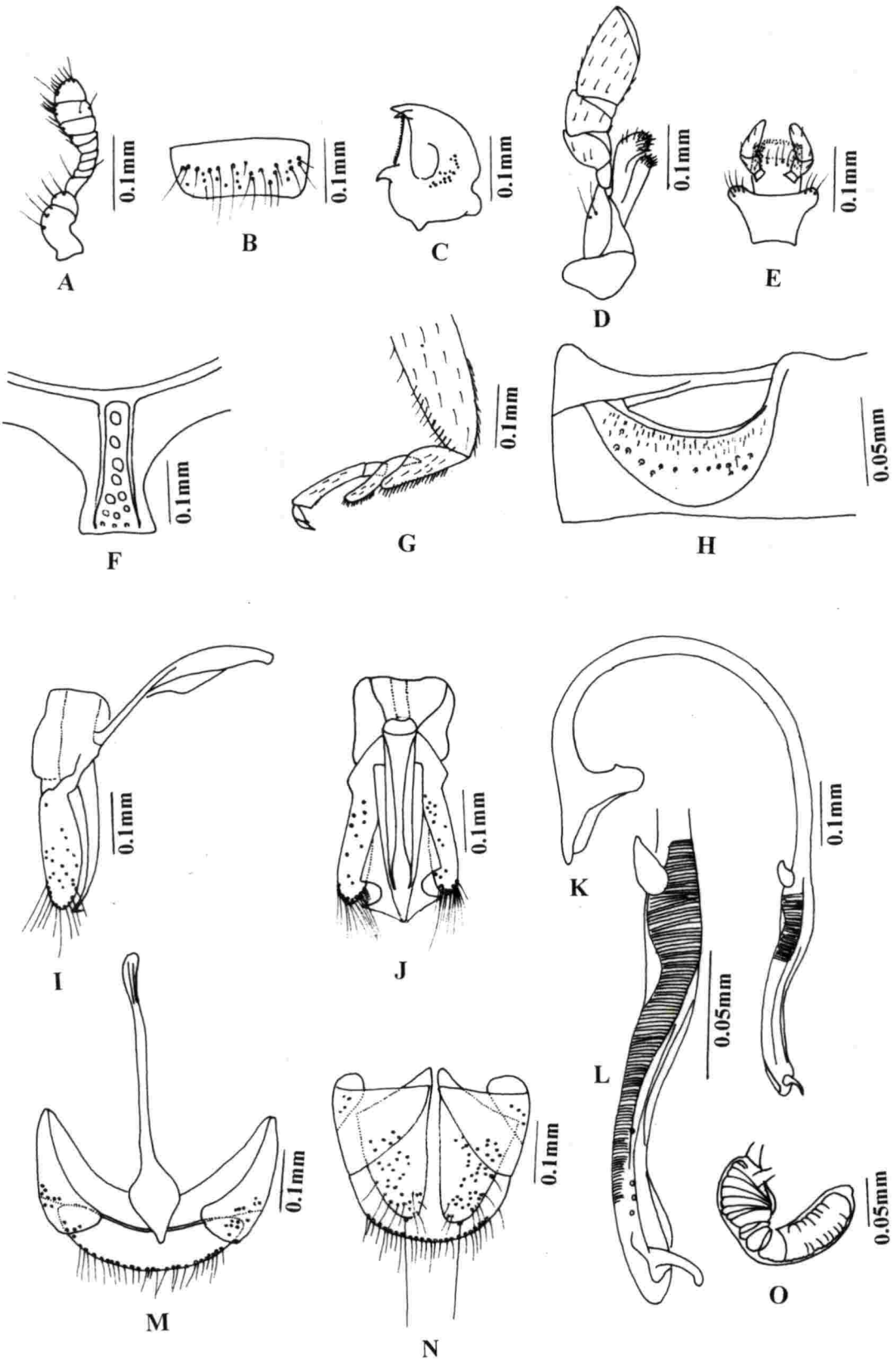


Fig. 17. ***Scymnus* (*Pullus*) *latemaculatus* Motschulsky**

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex; M. genital segment of male; N. genital segment of female; O. spermatheca

to dark brown; pronotum dark brown to black with yellowish brown or reddish orange anterior margin and lateral sides; scutellum black; elytra dark brown or black with two pairs of yellowish brown or orange yellow or reddish brown spots, anterior pair large, transverse and subquadrate, posterior pair slightly smaller; ventral side brown with dark brown to black pro-, meso- and metasternum; legs brown; antenna with 11 antennomeres; terminal maxillary palpomere more or less parallel sided; prosternal carina present and slightly convergent anteriorly; tarsi cryptotetramerous; post coxal line complete, area enclosed by lines sparsely punctate in the middle and smooth along the postcoxal line.

Male genitalia: Tegmen stout with penis guide slightly longer than parameres, apex of parameres with dense short setae of hairs; penis guide broad with a deep emargination on both the sides towards the terminal end in the ventral view; trabes slightly expanded apically; penis stout, apical 2/3rd curved, rest 1/3rd almost straight, expanded and sclerotized with ring like annulations and 'bud' like process in the beginning, preapical region of penis with a short appendage, penis capsule funnel/trumpet shaped; distal end of apophysis of ninth abdominal sternite is not distinctly dilated.

Female genitalia: Genital plates slightly tetragonal; hemisternite triangular; spermatheca small and broadly V-shaped.

Measurements: Male: Total length: 1.82 (1.70-1.89) mm, total width: 1.32 (1.30-1.44) mm, TL/TW: 1.37 (1.27-1.41), PL/PW: 0.50 (0.41-0.59), EL/EW: 1.02 (0.93-1.27), EW/PW: 1.26 (1.23-1.36); **Female:** Total length: 1.95 (1.75-2.20) mm, total width: 1.40 (1.21-1.56) mm, TL/TW: 1.39 (1.30-1.47), PL/PW: 0.50 (0.42-0.57), EL/EW: 1.04 (0.98-1.20), EW/PW: 1.25 (1.16-1.37).

Material: India: Kerala: 3♂, Vadakarapathy, 02.xii.2015 (VCV); 2♀, Chelakkara, 05.xii.2015 (VCV); 3♂, 1♀, Pattikkad, 09.xii.2015 (VCV); 2♂, 4♀, Vellanikkara, 11.i. 2016 (VCV); 2♂, 3♀, Kannara, 20.ii.2016 (VCV); 1♂, 1♀, Kayamkulam, 08.iii.2016 (VCV); 1♂, 2♀, Vellayani, 19.iv.2016 (VCV); **Karnataka:** 2♀, Shivamogga, 06.iv.2016 (VCV); 1♂, Raichur, 23.ix.2016 (VCV); **Tamil Nadu:** 1♂, Thiruchirappalli, 24.i.2016 (VCV); 3♂, 4♀, Madathukulam, 12.iv.2016 (VCV); 5♂, 4♀, Madurai, 08.iii.2016 (VCV).

Prey/Associated host: *Aphis craccivora* Koch on cowpea and *Gliricidia*; *A. gossypii* Glover on brinjal, chilli, *Colocasia*, *Eupatorium*, guava, *Hibiscus*; *Pentalonia nigronervosa* Coquerel on banana; on coconut (prey not known).

Karnataka: Raichur, Shivamogga; **Tamil Nadu:** Tiruchirappalli, Tiruppur, Madurai.

Remarks: This species resembles *Horniolus sororius* in colour and elytral pattern, but can be distinguished with its characteristic male genitalia and shape of prosternal carina.

4. 1. 2. 1. 1. 6. 6. *Scymnus (Pullus) pyrocheilus* Mulsant, 1853 (Plate 4d; Fig. 18)

Scymnus pyrocheilus Mulsant, 1853a: 281 (Perroud coll.).

Scymnus (Pullus) pyrocheilus: Mulsant, 1853b: 153.-Korschefsky, 1931: 144 (cat.).

Scymnus pyrocheilus: Crotch, 1874: 256.-Kapur, 1963: 22.

Diagnosis: Pronotum black with orange yellow patches on lateral and anterior margin, elytra with apical 1/4th region orange yellow and male genitalia is characterised by the presence of long, very fine thread like appendage.

Description: Body small, oval, strongly convex, densely pubescent with white hairs; head yellowish brown to brown, mouth parts dark brown; pronotum dark brown to blackish brown in the middle, anterior and lateral area brownish yellow to reddish orange; scutellum dark brown; elytra dark brown to black with apical 1/4th area orange yellow; ventral side yellowish or reddish brown except meso-, metasternum and anterior abdominal ventrite dark brown to black; legs yellow to yellowish brown; antenna with 11 antennomeres, last three antennomreres forming the club; terminal maxillary palpomere more or less parallel sided; prosternal carina slightly divergent posteriorly; tarsi cryptotetramerous; post coxal line complete, broadly curved, reaching near the posterior margin of first abdominal ventrite, area enclosed by lines coarsely punctate in the middle and smooth along the postcoxal line.

Male genitalia: Tegmen moderately stout; parameres with long dense hairs at the apical half; penis guide shorter than parameres reaching 2/3rd length of parameres in lateral view; penis guide widest at the base, gradually narrowed towards apex;

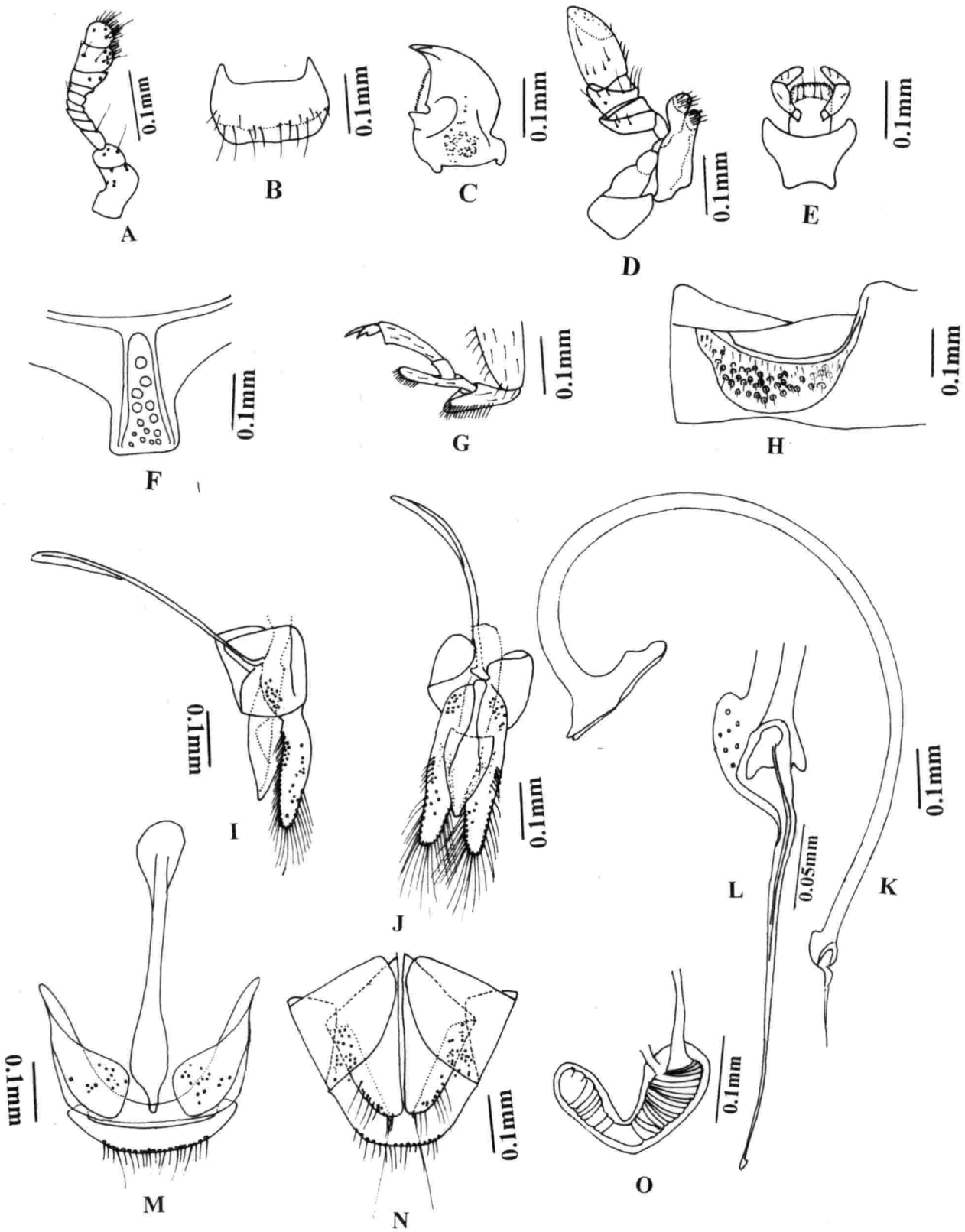


Fig. 18. *Scymnus* (*Pullus*) *pyrocheilus* Mulsant

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex; M. genital segment of male; N. genital segment of female; O. spermatheca

penis strongly curved, penis apex with a very fine, thread like appendage, penis capsule with long inner arm and short outer arm; apophysis of the ninth abdominal sternite expanded distally.

Female genitalia: Genital plates trigonal; hemisternites triangular; spermatheca broadly curved.

Measurements: Male: Total length: 1.99 (1.89-2.16) mm, total width: 1.47 (1.31-1.63) mm, TL/TW: 1.35 (1.30-1.42), PL/PW: 0.52 (0.51-0.55), EL/EW: 1.00 (0.90-1.07), EW/PW: 1.30 (1.25-1.38); **Female:** Total length: 2.04 (1.86-2.15) mm, total width: 1.52 (1.37-1.56) mm, TL/TW: 1.34 (1.19-1.47), PL/PW: 0.51 (0.41-0.54), EL/EW: 0.98 (0.87-1.14), EW/PW: 1.26 (1.21-1.42).

Material: India: Kerala: 1♂, 3♀, Cherpu, 01.viii.2015 (VCV); 1♂, Vadakkenchery, 16.x.2015 (VCV); 8♂, 11♀, Vellanikkara, 27.x.2015, 07.i.2016 (VCV); 1♂, 1♀, Kodannur, 07.xi.2015 (VCV); 1♂, 2♀, Vandazhy, 09.xii.2015 (VCV); 1♂, Kayamkulam, 09.iii.2016 (VCV); 2♂, 2♀, Vellayani, 19.iv.2016 (VCV); 3♂, 3♀, Avinissery, 02.ii.2017 (VCV); **Tamil Nadu:** 6♀, Tiruchirapalli, 23.i.2016 (VCV); 2♂, 4♀, Madathukulam 12.iv.2016 (VCV); 9♂, 7♀, Madurai, 08.ix.2016 (VCV); 3♂, 1♀, Periyakulam, 09.ix.2016 (VCV).

Prey/Associated host: *Aphis craccivora* on cowpea, *Gliricidia*; *Aphis gossypii* on brinjal, *Eupatorium*, Guava, *Hibiscus*; *Toxoptera odinae* (van der Goot) on *Annona*; on castor (prey not known).

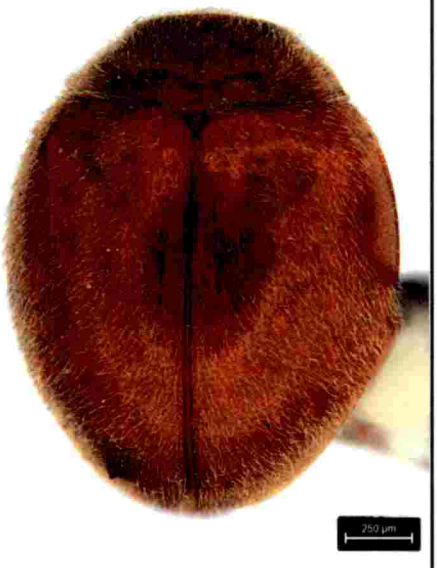
Remarks: *Scymnus* (*Pullus*) *pyrocheilus* resembles with *S.* (*P.*) *castaneus*, *S.* (*P.*) sp. 1 and *S.* (*P.*) sp. 3 with a long appendage in the penis apex. But the appendage is too thin and thread like when compared to other species.

4. 1. 2. 1. 1. 6. 7. *Scymnus* (*Pullus*) *utilis* Hoang, 1982 (Plate 5a, 5b; Fig. 19)

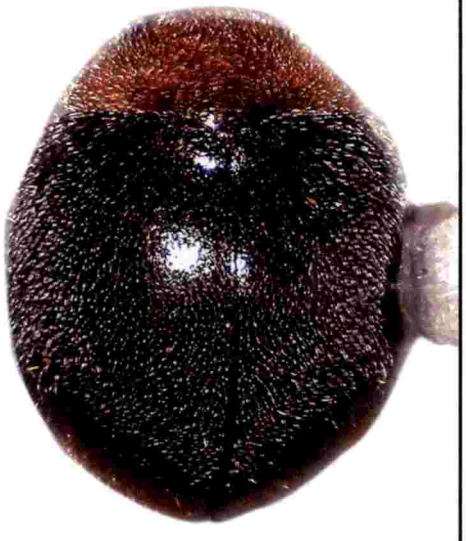
Scymnus (*Pullus*) *utilis* Hoang 1982: 154, 201.

Diagnosis: This species is characterised by the presence of tegmen with relatively larger phallobase, penis guide longer than parameres and penis apex broad with an appendage. Posterior margin of sixth abdominal ventrite is distinctly notched.

Description: Body small, broadly oval, hemispherical, convex, densely pubescent. Two morphotypes are identified based on colour of pronotum and elytra, i.



a. *Scymnus* (*Pullus*) *utilis*
Morphotype 1



b. *Scymnus* (*Pullus*) *utilis*
Morphotype 2

c. *Scymnus* (*Pullus*) sp.1

d. *Scymnus* (*Pullus*) sp.2

Plate 5. Species of Scymnini

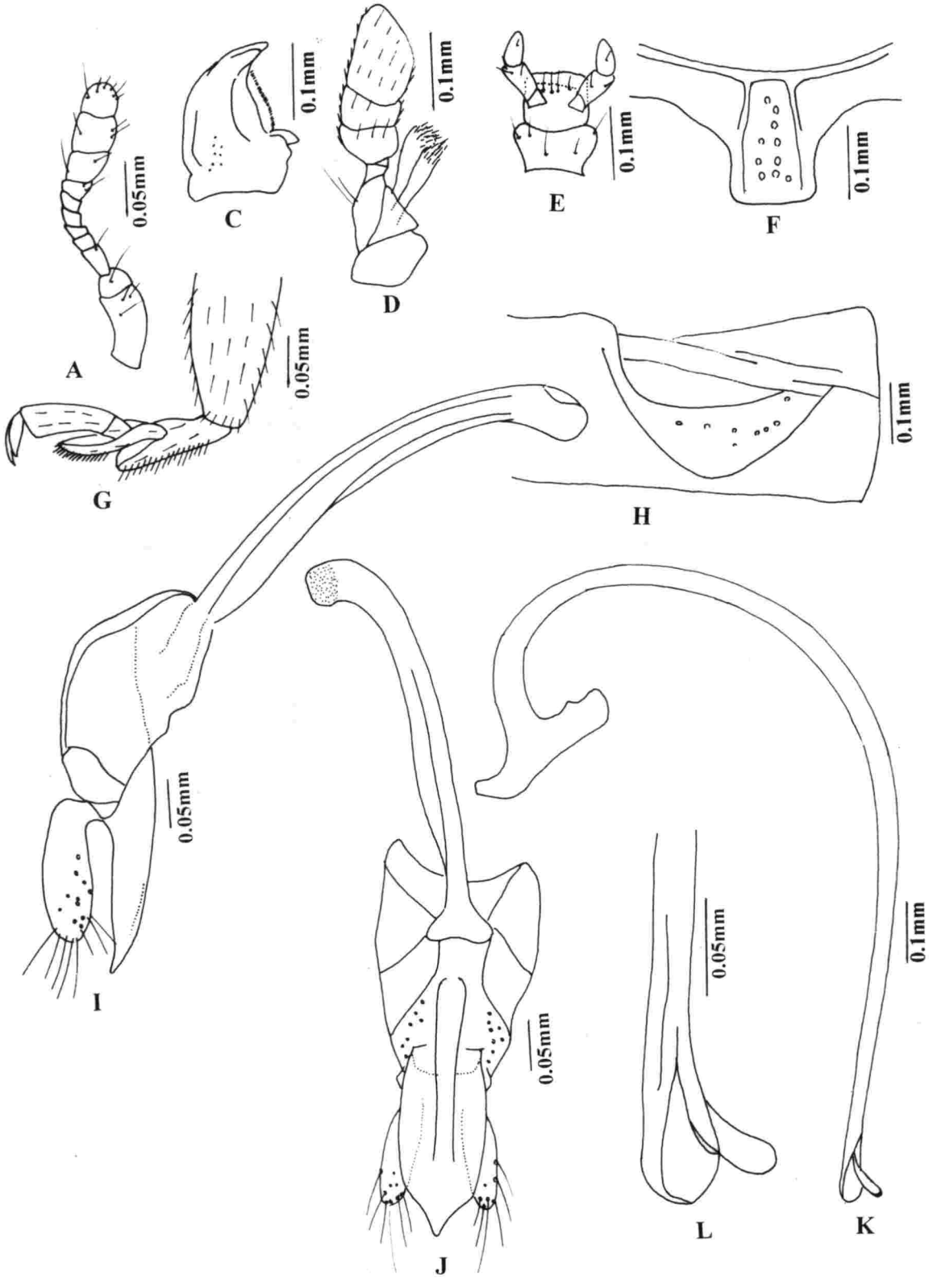


Fig. 19. *Scymnus* (*Pullus*) *utilis* Hoang

A. antenna; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex

uniformly brownish yellow, ii. pronotum reddish brown, elytra black with reddish orange apex; antenna with 11 antennomeres, last three antennomeres forming the antennal club; last segment of maxillary palp weakly divergent; prosternal carina slightly divergent posteriorly; tarsi cryptotetramerous; post coxal line complete, broadly curved, area enclosed by lines almost smooth.

Male genitalia: Tegmen with relatively larger phallobase; parameres a few short hairs at the apex; penis guide relatively broader, longer than parameres, penis guide widest at the base, parallel nearly $3/4^{th}$ of length and then narrowed to the apex in ventral view; penis strongly curved at the basal half, penis apex broad with a short appendage, penis capsule with long inner arm and short outer arm.

Measurements: Total length: 1.95 mm, total width: 1.38 mm.

Material: India: Kerala: 1♂, Kottepadam, 17.ix.2015 (VCV); 1♂, 1♀, Tiruchirapalli, 23.i.2016 (VCV); 1♂, Avinissery, 24.i.2016 (VCV).

Prey/Associated host: Mealybugs on bhindi, guava, *Hibiscus*.

Remarks: One of the morphotype of *Scymnus* (*Pullus*) *utilis*, with uniform yellowish elytra resembles with species of Scymnini with yellowish elytra. But, *S.* (*P.*) *utilis* is more round in shape and sixth abdominal ventrite is distinctly notched in the posterior margin compared to other species. The male genitalia with relatively larger phallobase.

4. 1. 2. 1. 1. 6. 8. *Scymnus* (*Pullus*) sp. 1 (Plate 5c; Fig. 20)

Diagnosis: This species is identified by reddish brown pronotum and elytra, penis guide shorter than parameres and penis with a long thread like appendage at the apex.

Description: Body medium sized, slightly oval, moderately convex, densely pubescent with silvery white hairs; head, pronotum, scutellum and elytra light reddish brown to brown, mouth parts dark brown; ventral side light brown to brown, pro- and meso sternites darker; antenna with 11 antennomeres, last three antennomeres forming the antennal club; terminal segment of maxillary palp nearly parallel sided; prosternal carnina very slightly divergent posteriorly; legs cryptotetramerous; post coxal line on first abdominal ventrite complete, deeply

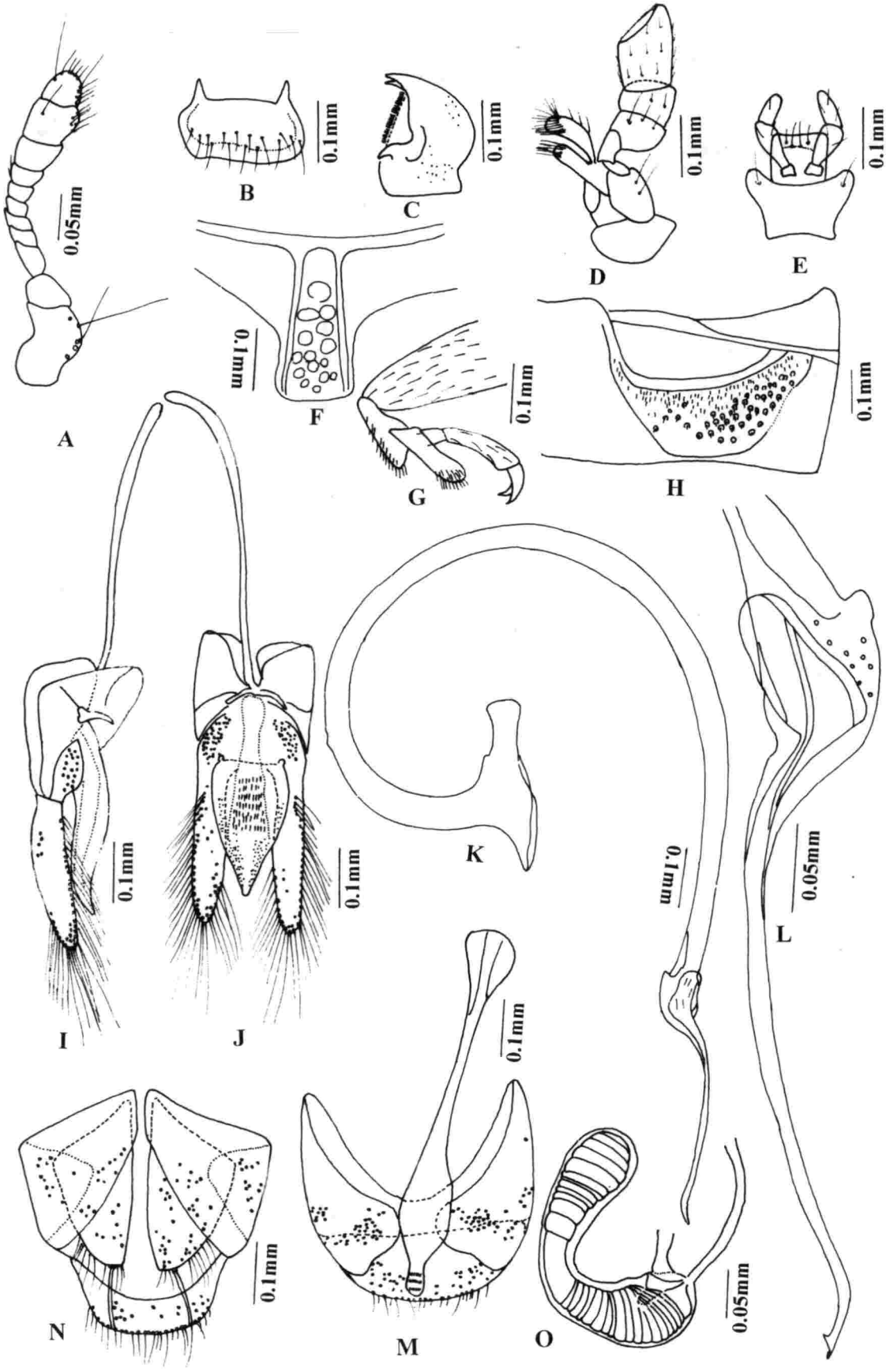


Fig. 20. *Scymnus* (*Pullus*) sp. 1

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex; M. genital segment of male; N. genital segment of female; O. spermatheca

curved, line reaches very close to the posterior margin of abdominal ventrite and runs parallel for a short distance, thereafter strongly curved upwards, lines faded for a short distance and reaches anterior margin of the first abdominal ventrite, area enclosed by lines sparsely punctate in the middle.

Male genitalia: Tegmen stout; parameres with dense long hairs at the apex; penis guide shorter than parameres; penis stout, strongly curved, penis capsule with long inner arm compared to short outer arm, penis apex with a long appendage; distal end of apophysis of ninth sternite is distinctly dilated.

Female genitalia: Hemisternite triangular; spermatheca broadly V-shaped.

Measurements: Male: Total length: 2.10 (2.01-2.25) mm, total width: 1.59 (1.53-1.68) mm, TL/TW: 1.31 (1.30-1.35), PL/PW: 0.56 (0.54-0.58), EL/EW: 1.03 (0.98-1.13), EW/PW: 1.46 (1.43-1.49); **Female:** Total length: 2.25 (2.09-2.42) mm, total width: 1.67 (1.63-1.77) mm, TL/TW: 1.34 (1.29-1.38), PL/PW: 0.52 (0.45-0.61), EL/EW: 1.04 (0.95-1.13), EW/PW: 1.37 (1.30-1.52).

Material: India: Kerala: 1♂, 2♀, Vellanikkara, 03.ix.2015 (VCV); 3♀, Vandazhy, 30.vi.2016 (VCV); **Karnataka:** 12♂, 9♀, Shivamogga, 06.iv.2016 (VCV); 1♂, 3♀, Dharwad, 16.ix.2016 (VCV); **Tamil Nadu:** 1♂, 1♀, T. Kallupetti, 08.ix.2016 (VCV); 1♂, 2♀, Madurai, 09.ix.2016 (VCV)

Prey/Associated host: *Aphis craccivora* on cowpea, *Gliricidia*; *A. gossypii* on cotton, guava.

Remarks: The male genitalia of *Scymnus* (*Pullus*) sp. 1 is closely related to that of *S.* (*P.*) sp. 3. and both of these have similarity to *S.* (*P.*) *posticalis* Sicard, which has to be confirmed further. *S.* (*P.*) sp.1 is relatively larger. The penis apex of *S.* (*P.*) sp.1 is distinctly longer compared to *S.* (*P.*) sp.3. Similarity in male genitalia of *S.* (*P.*) sp. 1 with *S.* (*P.*) *castaneus*, *S.* (*P.*) *pyrocheilus* is discussed in chapters 4. 1. 2. 1. 1. 6. 3. and 4. 1. 2. 1. 1. 6. 6.

4. 1. 2. 1. 1. 6. 9. *Scymnus* (*Pullus*) sp. 2 (Plate 5d; Fig. 21)

Diagnosis: This species is identified by penis guide shorter than parameres reaching 2/3rd of length parameres and penis with a short appendage at the apex.

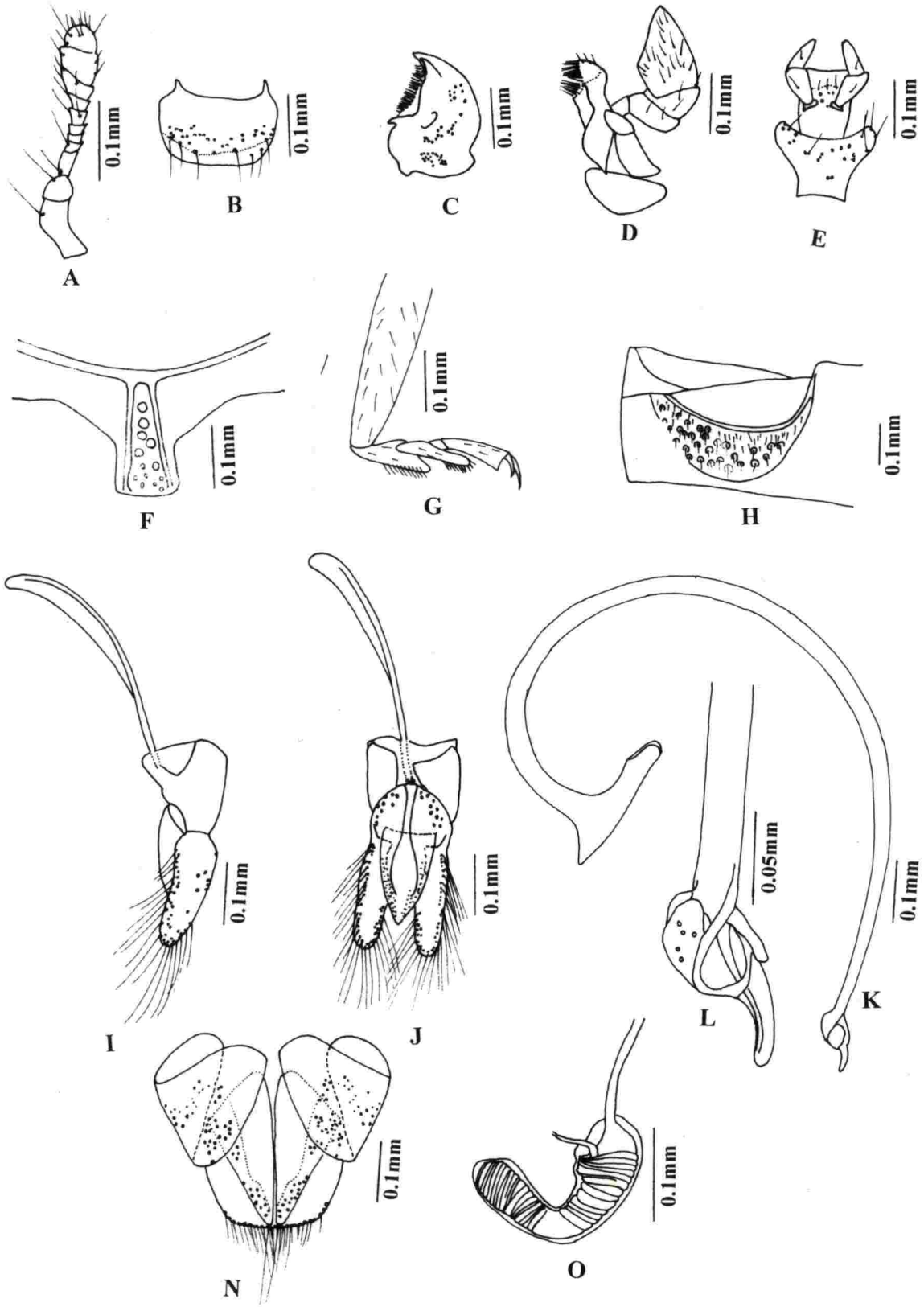


Fig. 21. *Scymnus* (*Pullus*) sp. 2

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex; N. genital segment of female; O. spermatheca

Description: Body slightly oval, small, convex, dorsum pubescent; head, mouth parts and pronotum, elytra orange yellow; ventral side orange yellow with pro-, meso-, metasternum and anterior part of first abdominal ventrite darker; antenna with 11 antennomeres, last three antennomeres forming the club; terminal maxillary palpomere weakly divergent; prosternal carina present, weakly divergent posteriorly; tarsi cryptotetramerous; post coxal line complete, broadly curved, reaching near the posterior margin of first abdominal ventrite, line after curvature faded for short length before reaching to anterior margin, area enclosed by lines coarsely punctate towards outside.

Male genitalia: Tegmen moderately stout; parameres with long dense hairs at the apex; penis guide shorter than parameres reaching 2/3rd length of parameres in lateral view, trabes with membraneous expansion 3/4th length its distal end; penis strongly curved at the basal 2/3rd length, penis apex with a short appendage, penis capsule with long inner arm and short outer arm.

Female genitalia: Genital plates trigonal; hemisternites triangular; spermatheca broadly V-shaped.

Measurements: Total length: 1.94 mm, total width: 1.42 mm, TL/TW: 1.36, PL/PW: 0.55, EL/EW: 1.09, EW/PW: 1.35.

Material: India: Karnataka: 1♂, 2♀, Dharwad, 17.ix.2016 (VCV).

Prey/Associated host: *Aphis gossypii* on *Hibiscus*.

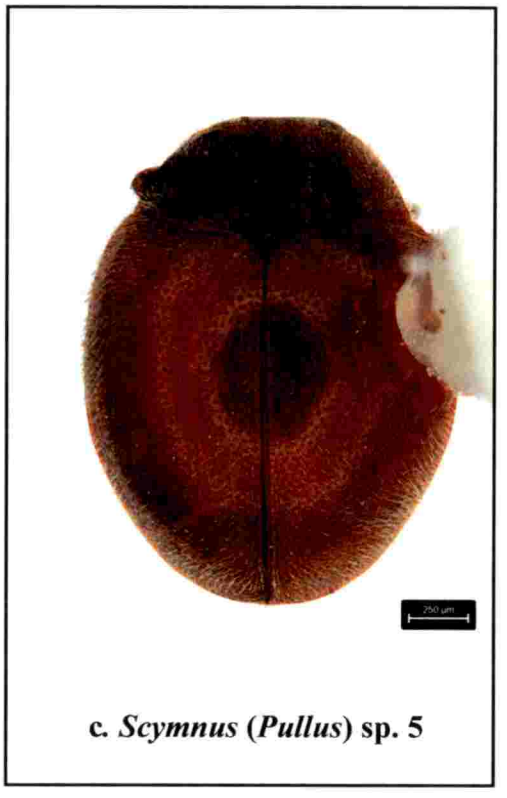
4. 1. 2. 1. 1. 6. 10. *Scymnus* (*Pullus*) sp. 3 (Plate 6a; Fig. 22)

Diagnosis: Pronotum and elytra brownish black, penis guide shorter than parameres reaching 2/3rd length of parameres, penis with thread like appendage at the apex.

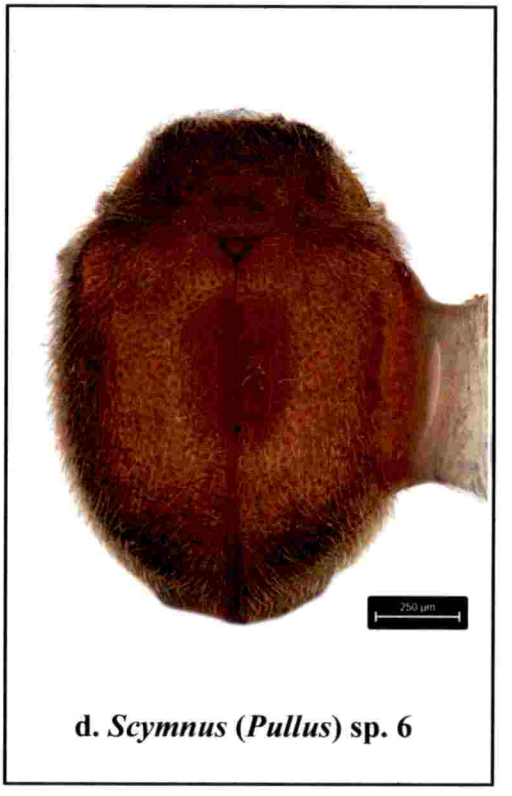
Description: Body small, shortly oval, convex, dorsum densely pubescent with golden coloured hairs; head brownish black with relatively light coloured mouth parts; dorsum black with anterior margin and lateral area light coloured; elytra brownish black with relatively lighter apical region; ventral side dark brown; legs brown with light coloured tarsi; antenna with 11 antennomeres, last three antennomeres forming the club; terminal maxillary palpomere weakly divergent;

a. *Scymnus* (*Pullus*) sp. 3

b. *Scymnus* (*Pullus*) sp. 4



c. *Scymnus* (*Pullus*) sp. 5



d. *Scymnus* (*Pullus*) sp. 6

Plate 6. Species of Scymnini

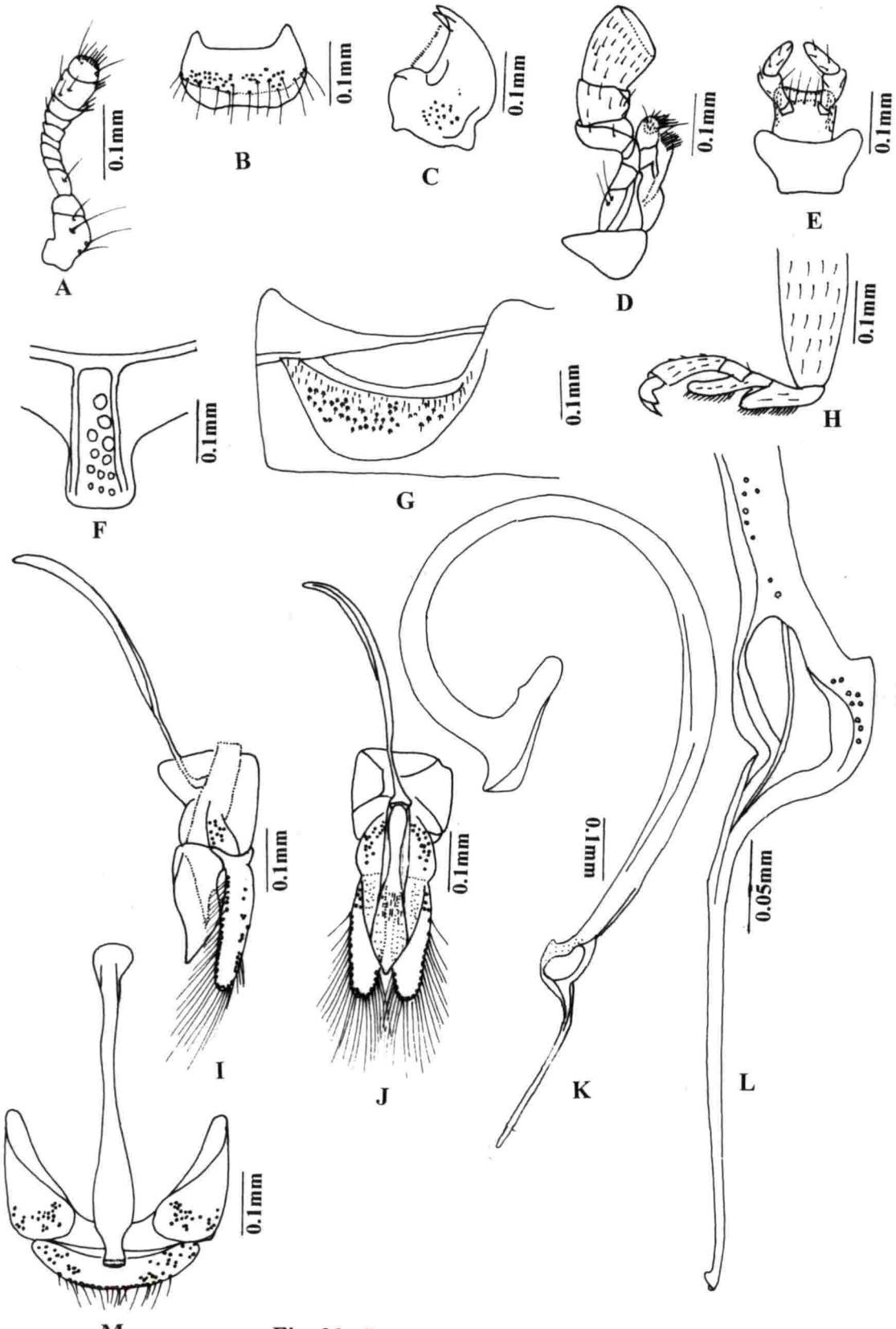


Fig. 22. *Scymnus* (*Pullus*) sp. 3

A.antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex; M. genital segment of male

prosternal carina present and almost parallel; tarsi cryptotetramerous; post coxal line complete, broadly curved, reaching near the posterior margin of first abdominal ventrite, area enclosed by lines moderately punctate towards upper half and smooth towards lower half.

Male genitalia: Tegmen moderately stout; parameres with long dense hairs at the apex; penis guide shorter than parameres reaching 2/3rd length of parameres in lateral view, penis guide widest at the base, gradually narrowed towards apex; trabes without any dilation distally; penis strongly curved at 3/4th of its length at the base, penis apex with thread like appendage, penis capsule with long inner arm and short outer arm; apophysis of the ninth abdominal sternite expanded distally.

Measurements: Male: Total length: 1.89 mm, total width: 1.27 mm, TL/TW: 1.48, PL/PW: 0.53, EL/EW: 1.14, EW/PW: 1.28; **Female:** Total length: 1.91 mm, total width: 1.37 mm, TL/TW: 1.39, PL/PW: 0.51, EL/EW: 1.12, EW/PW:1.24 .

Material: India: Kerala: 2♂, 2♀, Panniyur, 21.xii.2015 (VCV).

Prey/Associated host: *Aphis craccivora* on *Gliricidia.*

Remarks: The resemblance of this species with *Scymnus* (*Pullus*) *castaneus*, *S.* (*P.*) *pyrocheilus* and *S.* (*P.*) sp. 1. have been discussed in chapters 4. 1. 2. 1. 1. 6. 3., 4. 1. 2. 1. 1. 6. 6. and 4. 1. 2. 1. 1. 6. 8.

4. 1. 2. 1. 1. 6. 11. *Scymnus* (*Pullus*) sp. 4 (Plate 6b; Fig. 23)

Diagnosis: This species can be identified by dark brown to black elytra with reddish brown lateral and apical margin, penis with a thread like appendage at sub apical position and parameres longer than penis guide with setae on almost entire length.

Description: Body small, short oval, strongly convex, densely pubescent with whitish hairs; head reddish brown with reddish brown to dark brown mouth parts; pronotum dark brown to blackish brown in the middle, anterior and lateral area brownish yellow to reddish orange; scutellum dark brown; elytra dark brown to black with brownish yellow to reddish orange border on lateral sides and apical region; ventral side reddish brown except meso-, metasternum and middle portion of first abdominal ventrite darker; legs reddish brown; antenna with 11 antennomeres, last three antennomeres forms club; terminal maxillary palpomere

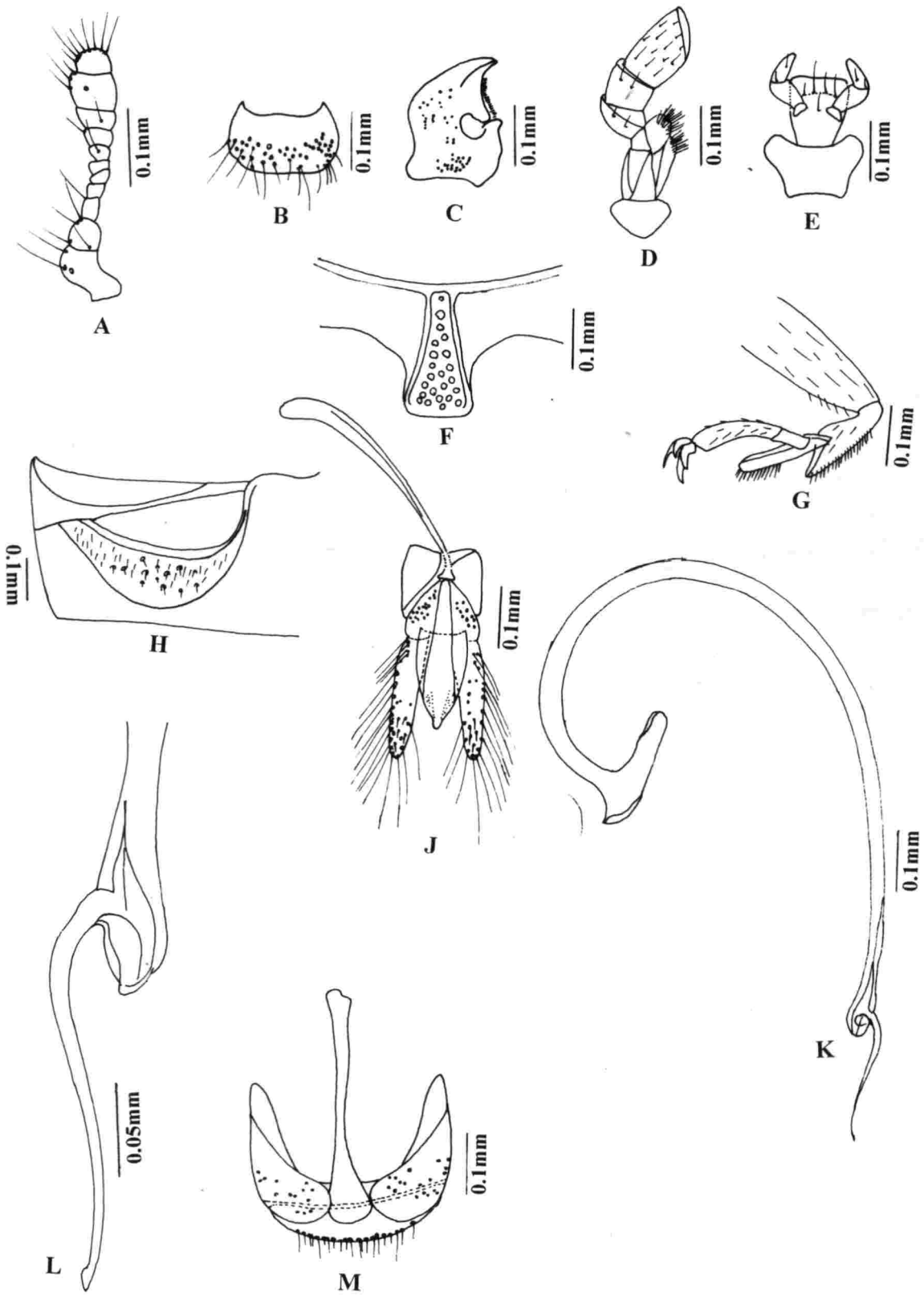


Fig. 23. ***Scymnus* (*Pullus*) sp. 4**

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; J. tegmen, ventral; K. penis; L. penis apex; M. genital segment of male

almost parallel sided; prosternal process with posteriorly divergent prosternal carina; tarsi cryptotetramerous; post coxal line complete, area enclosed by lines sparsely punctate and smooth near the postcoxal line.

Male genitalia: Tegmen moderately stout; parameres with long, dense setae at apex; penis guide shorter than parameres, narrowed to a blunt apex; penis strongly curved at the basal 2/3rd length, preapical region of penis bears curved thread like appendage, penis capsule with long, narrow inner arm and short outer arm; apophysis of the ninth sternite not expanded distally.

Measurements: Male: Total length: 1.87 (1.84 -1.99) mm, total width: 1.37 (1.28 - 1.45) mm, TL/TW: 1.36 (1.26 -1.43), PL/PW: 0.49 (0.43 – 0.55), EL/EW: 1.03 (0.95 – 1.16), EW/PW: 1.34 (1.33 – 1.35); **Female:** Total length: 2.05 (1.93 – 2.22) mm, total width: 1.46 (1.14 – 1.59) mm, TL/TW: 1.39 (1.31 – 1.48), PL/PW: 0.51 (0.47 – 0.54) , EL/EW: 1.06 (1.02 – 1.12), EW/PW: 1.33 (1.28 – 1.41).

Material: India: Kerala: 1♂, 1♀, Parakkad, 05.xii.2015 (VCV); 1♀, Marakkal, 09.xi.2015 (VCV); 1♀, Vellanikkara, 08.xii.2015, 27.x.2016 (VCV); 2♂, Ambalavayal, 25.ii.2016 (VCV); 1♀, Kayamkulam, 09.iii.2016 (VCV); **Karnataka:** 1♀, Bengaluru, 22.ix.2017.

Prey/Associated host: *Rhopalosiphum maidis* (Fitch) on maize; aphids on tulsi; on banana, *Helecteres isora* (prey not known).

Remarks: This species resembles with *Scymnus* (*Pullus*) sp. 5, both with a long appendage at the subapical region of penis apex. But, in *S.* (*P.*) sp.4, the penis guide is shorter than parameres, whereas in *S.* (*P.*) sp. 5, penis guide is longer than parameres.

4. 1. 2. 1. 1. 6. 12. *Scymnus* (*Pullus*) sp. 5 (Plate 6c; Fig. 24)

Diagnosis: This species can be distinguished by orange yellow elytra, a thread like appendage at preapical region of penis and parameres shorter than penis guide with setae on distal 1/3rd position.

Diagnostic characters: Body small, round oval, strongly convex, dorsum pubescent with yellowish white hairs; head yellowish brown with dark mouth parts; pronotum yellowish brown with light anterior and lateral margin; elytra orange

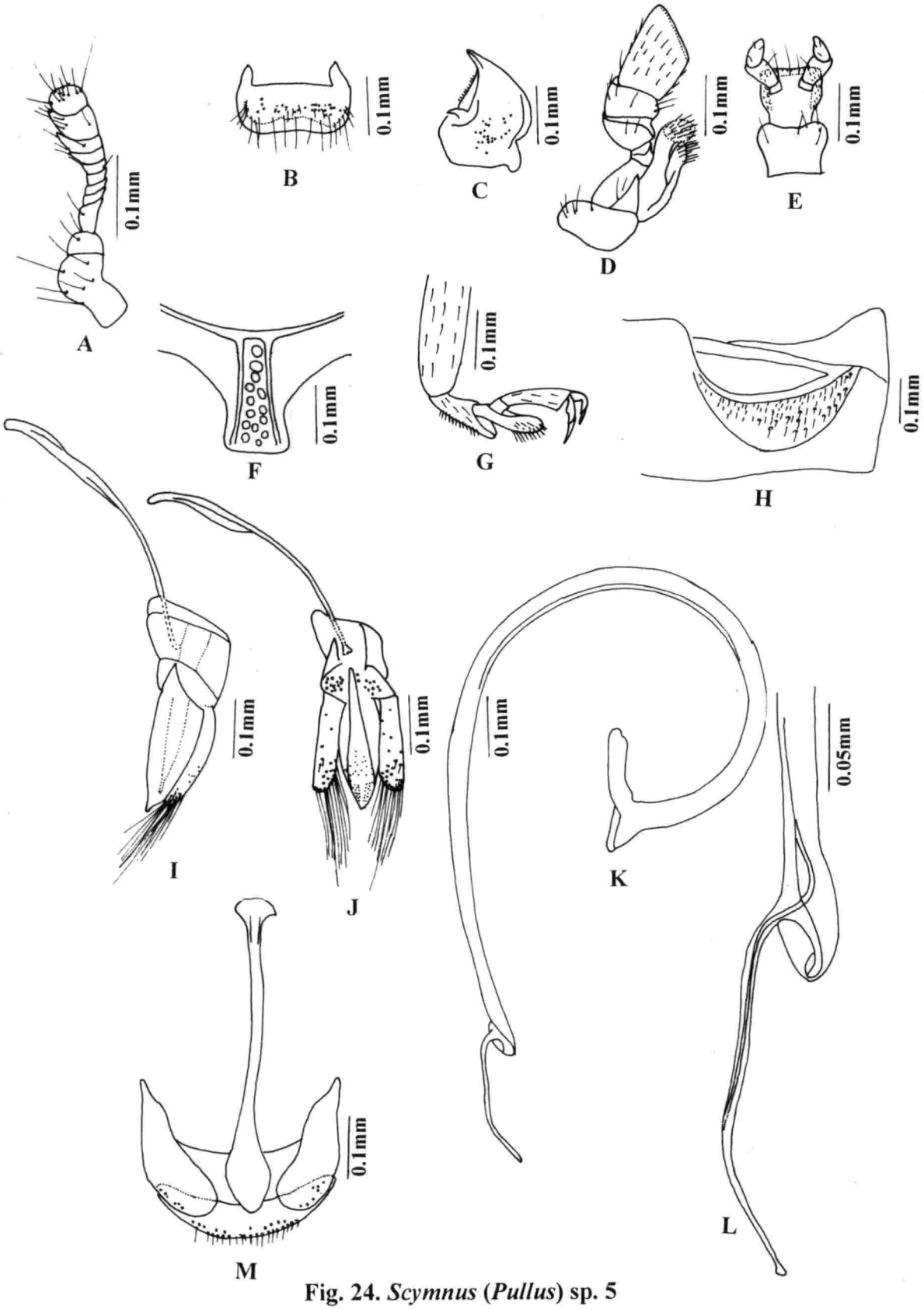


Fig. 24. *Scymnus* (*Pullus*) sp. 5

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex; M. genital segment of male

yellow; ventral side yellowish brown with slightly darker meso- and metasternum; legs orange yellow; antenna with 11 antennomeres, last three antennomeres forms club; terminal palpomere of maxillary palp weakly divergent; prosternal carina weakly divergent; tarsi cryptotetramerous; post coxal line complete, area enclosed by lines smoothly punctate, more towards the lateral area.

Male genitalia: Tegmen moderately stout, paramers broad and with dense setae towards the apex; penis guide longer than parameres; penis strongly curved at the basal 2/3rd length, penis apex bears curved thread like appendage, penis capsule with long, narrow inner arm and short outer arm, margin of inner arms parallel; apophysis of the ninth sternite expanded distally.

Measurements: Male: Total length: 1.83 mm, total width: 1.33 mm, TL/TW: 1.37, PL/PW: 0.58, EL/EW: 1.06, EW/PW: 1.40; **Female:** Total length: 1.97mm, total width: 1.50 mm, TL/TW:1.31, PL/PW: 0.55, EL/EW: 1.01, EW/PW: 1.37.

Material: India: Kerala: 2♂, 1♀, Panniyur, 21.xii.2015 (VCV); 1♂, 1♀, Avinissery, 11.ix.2016 (VCV); **Tamil Nadu:** 1♂, Madurai, 07.ix.2016 (VCV).

Prey/Associated host: *Aphis gossypii* on chilli, guava; *Pentalonia nigronervosa* Coquerel on banana.

Remarks: Similarity between *Scymnus* (*Pullus*) sp. 4 and *S.* (*P.*) sp. 5 are discussed in the chapter 4. 1. 2. 1. 1. 6. 11.

4. 1. 2. 1. 1. 6. 13. *Scymnus* (*Pullus*) sp. 6 (Plate 6d; Fig. 25)

Diagnosis: This species is characterised by presence of penis apex which is bent inwards at an obtuse angle.

Description: Body small, slightly elongated, moderately convex and dorsum pubescent; head, pronotum, elytra yellow to orange yellow with light coloured mouth parts; ventral side yellow; antenna with 11 antennomeres, last three antennomeres forming club; terminal maxillary palpomere weakly divergent; prosternal carina divergent posteriorly; tarsi cryptotetramerous; post coxal line of first abdominal ventrite complete, narrowly curved, area enclosed by line sparsely punctate.

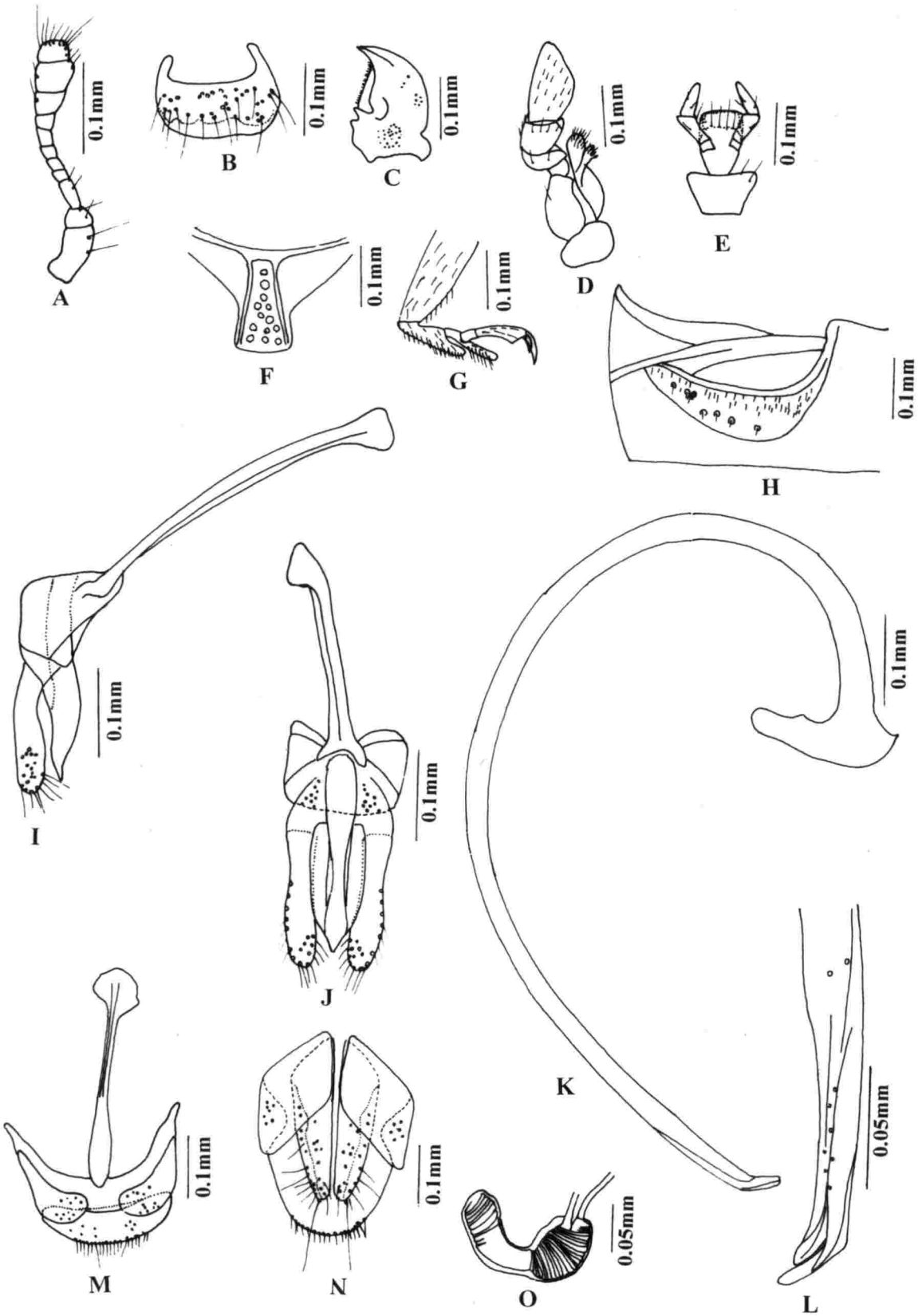


Fig. 25. *Scymnus* (*Pullus*) sp. 6

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex; M. genital segment of male; N. genital segment of female; O. spermatheca

Male genitalia: Tegmen moderately stout; parameres with a few short hairs at the apex; penis guide shorter than paramers, slightly curved towards the apex in lateral view; trabes knob like/enlarged distally; penis broadly curved throughout the length, penis apex blunt, bent at an obtuse angle, penis capsule with a long inner arm, very short outer arm; distal end of apophysis of ninth sternite is distinctly dilated with a characteristic shape.

Female genitalia: Genital plates trigonal; hemisternites triangular; spermatheca broadly curved.

Measurements: Total length: 1.56 (1.40-1.73) mm, total width: 1.13 (1.02-1.25) mm, TL/TW: 1.39 (1.34-1.49), PL/PW: 0.54 (0.51-0.58), EL/EW: 1.03 (0.95-1.16), EW/PW: 1.29 (1.18-1.39).

Material: India: Kerala: 3♂, 5♀, Pattikkad, 30.ix.2015, 20.x.2015, 16.xii.2016 (VCV); 1♂, Perumbavoor, 28.x.2015 (VCV); 1♂, 1♀, Tavanur, 12.xii.2015 (VCV); 1♀, Panniyur, 21.xii.2015 (VCV); 4♂, 3♀, Vellanikkara, 16.xii.2015 (VCV); 3♂, 5♀, Chalakkudy, 11.iii.2016 (VCV); 1♂, 2♀, Avinissery, 13.iii.2016 (VCV); 10♂, 13♀, Payyanam, 23.iii.2016 (VCV); 5♂, 3♀, Vadakkenchery, 10.ii.2017 (VCV).

Prey/Associated host: *Coccidohystrix insolita* on brinjal; *Ferrisia virgata* on black pepper, colocasia, long pepper; *Nipaecoccus viridis* (Newstead) on *Mucuna*; *Phenacoccus solenopsis* Tinsley on *Lantana*, *Aerva lanata*; *Pseudococcus jackbeardsleyi* Gimpel and Miller on *Celosia*.

Remarks: This species resembles to one of the morphotypes of *Scymnus* (*Pullus*) *coccivora* and *S.* (*P.*) sp. 9 in external appearance with orange yellow colour without any elytral marking. This species vary distinctly from above species with penis apex bent at an obtuse angle.

4. 1. 2. 1. 1. 6. 14. *Scymnus* (*Pullus*) sp. 7 (Plate 7a; Fig. 26)

Diagnosis: This species can be identified by the presence of slender parameres which is almost equal to penis guide and a simple, elongated penis apex.

Description: Body small, oval, moderately convex, densely pubescent with short white hairs; head, mouth parts and pronotum yellowish orange to orange yellow;

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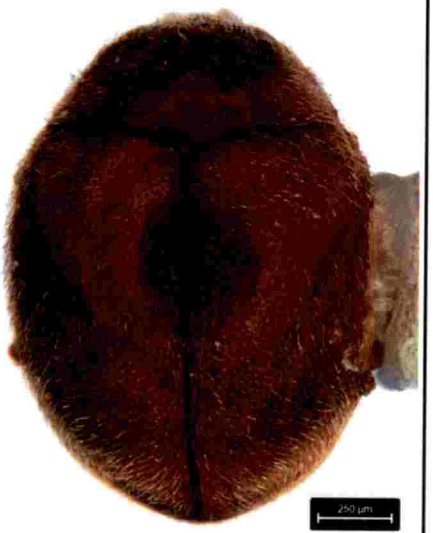
a. *Scymnus* (*Pullus*) sp. 7

b. *Scymnus* (*Pullus*) sp. 8



c. *Scymnus* (*Pullus*) sp. 9

d. *Scymnus* (*Pullus*) sp. 10

Plate 7. Species of Scymnini

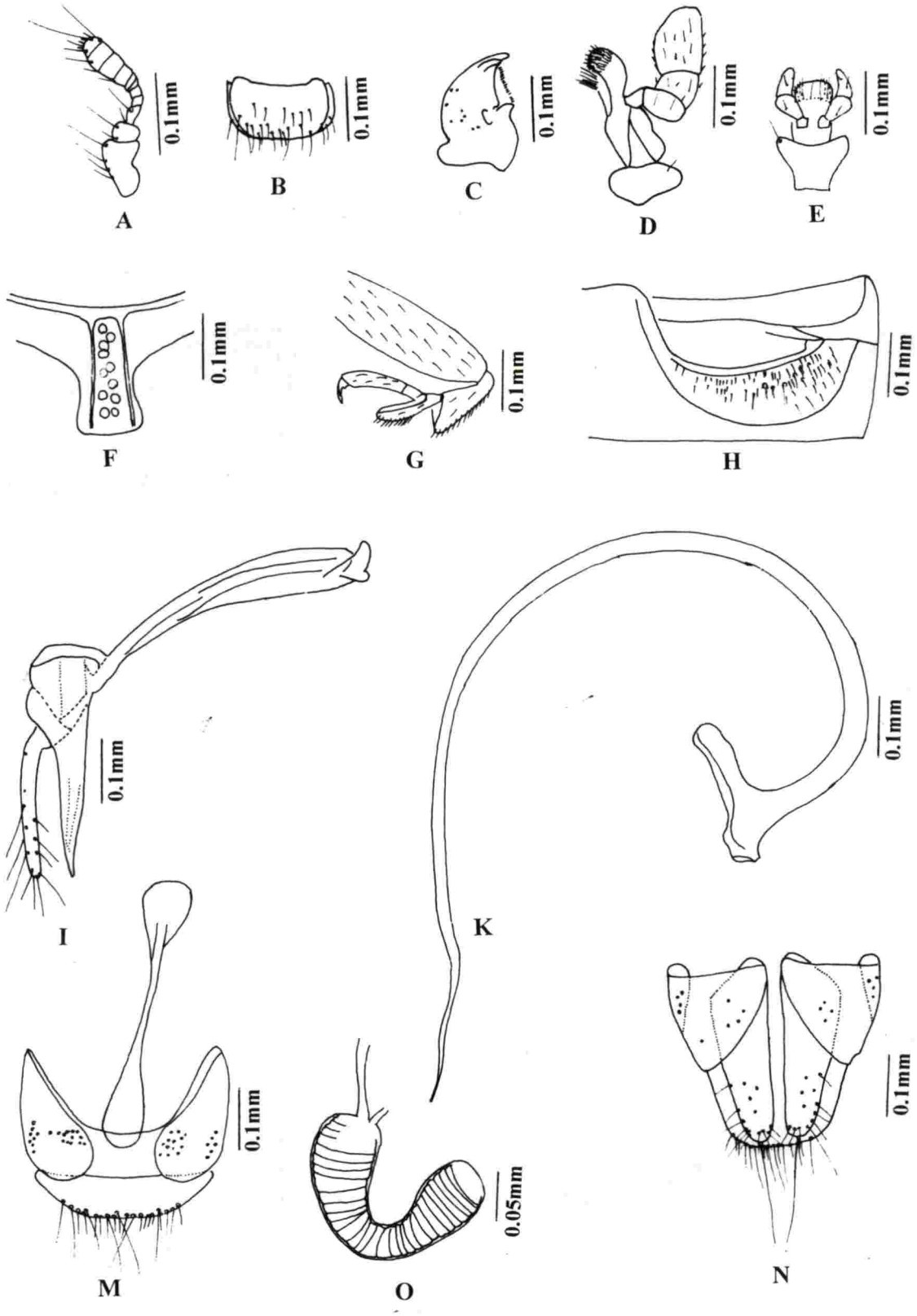


Fig. 26. *Scymnus* (*Pullus*) sp. 7

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; K. penis; M. genital segment of male; N. genital segment of female; O. spermatheca

scutellum yellow or black; elytra black with apical region orange yellow; ventral side brownish with posterior part of abdomen light coloured; legs yellowish brown; antenna with 11 antennomeres, terminal four antennomeres forming the antennal club; terminal maxillary palpomere weakly divergent; prosternal carina almost parallel; tarsi cryptotetramerous; post coxal line complete, broadly curved, area enclosed by line sparsely punctate, smooth along the posterior margin of post coxal line.

Male genitalia: Parameres slender with a few medium sized hairs at the apex; penis guide elongated, subtriangular, almost equal to parameres; distal end of trabes dilated; penis curved at the basal $3/5^{th}$ length, penis apex simple, elongated, penis capsule with long inner arm and short outer arm; apophysis of the ninth abdominal segment expanded distally.

Female genitalia: Hemisternites triangular; spermatheca curved medially.

Measurements: Male: Total length: 1.63 (1.50 - 1.74) mm, total width: 1.13 (1.06 - 1.21) mm, TL/TW: 1.43 (1.41 - 1.45), PL/PW: 0.53 (0.47 - 0.59), EL/EW: 1.08 (1.01 - 1.15) , EW/PW: 1.26 (1.17 - 1.34); **Female:** Total length: 1.80 (1.61 - 1.95) mm, total width: 1.28 (1.10 - 1.46) mm, TL/TW: 1.40 (1.33 - 1.46), PL/PW: 0.54 (0.47 - 0.58), EL/EW: 1.09 (1.04 - 1.13), EW/PW: 1.25 (1.19 - 1.31) .

Material: India: Kerala: 2♂, 3♀, Elavally, 07.ix.2015, 16.ix.2015 (VCV); 3♂, 3♀, Vellanikkara, 08.xii.2015 (VCV); 1♂, 1♀, Vazhakulam 25.ii.2016 (VCV); 2♂, 3♀, Avinissery, 28.ii.2016 (VCV); 3♀, Mukkam, 05.iii.2016 (VCV); 2♂, 2♀, Kumarakom, 14.iii.2016 (VCV); 3♂, 6♀, Banasura sagar, 10.iv.2017 (VCV); 7♂, 8♀, Ambalavayal, 12.iv.2017 (VCV).

Prey/Associated host: *Dysmicoccus brevipes* (Cockerell) and *Dysmicoccus neobrevipes* (Beardsley) on pineapple; *Phenacoccus solenopsis* on *Hibiscus*; *Planococcus citri* on coffee; *Pseudococcus* sp on coconut; mealybug on *Hibiscus*; on arecanut (prey not known).

Remarks: *Scymnus* (*Pullus*) sp. 7 resembles to *S. saciformis* in elytral pattern, but can be distinguished by the presence of antenna with 11 antennomeres and cryptotetramerous tarsi. This species is separated from *S.* (*P.*) sp. 8. with penis guide almost equal to parameres and preapical region of penis without dilation.

4. 1. 2. 1. 1. 6. 15. *Scymnus* (*Pullus*) sp. 8 (Plate 7b; Fig. 27)

Diagnostic characters: Body small, short oval, dorsum densely pubescent. Head and mouth parts light brown; pronotum orange ; elytra black with yellowish orange tip; ventral side black except prosternum and yellow; elytra black with apical 1/4th region orange yellow; antenna with 11 antennomeres; terminal maxillary palpomere almost parallel; prosternal process with very weakly divergent carina; tarsi cryptotetramerous; post coxal line broadly curved, area enclosed by the line smoothly punctate along the the coxal line, rest area smooth.

Male genitalia: Parameres with medium sized hairs at the apex; penis guide distinctly shorter than parameres; penis curved at the basal 1/3rd length, penis apex simple, elongated, preapical region broad; penis capsule with long inner arm and short outer arm.

Measurements: Total length: 1.74 mm, total width: 1.31 mm.

Material: India: Kerala: 1♂, Kayakulam, 08.iii.2016 (VCV).

Prey/Associated host: Mealybugs on tapioca.

Remarks: *Scymnus* (*Pullus*) sp. 8 resembles to *S. saciformis* in external appearance, but can be distinguished by the presence of antenna with 11 antennomeres and cryptotetramerous tarsi. This species is separated from *S.* (*P.*) sp. 7. with shorter penis guide with respect to parameres and slightly swollen area in the subapical region of penis.

4. 1. 2. 1. 1. 6. 16. *Scymnus* (*Pullus*) sp. 9 (Plate 7c; Fig. 28)

Diagnosis: This species can be identified by the following characters: stout tegmen with a prominent keel, penis guide widest at the middle and tapering towards a blunt apex, penis apex with two finger like blunt projection of subequal length and preapical region with a semicircular projection towards inner side.

Description: Body small, convex, round, dorsum densely pubescent; head yellowish brown to light brown; mouth parts golden yellow to yellowish brown; pronotum brownish yellow to brown with light coloured anterior margin and lateral sides; elytra yellowish brown to brown with light coloured posterior 1/4th area, in some anterior margin of elytra and line of suture dark and prominent; ventral side

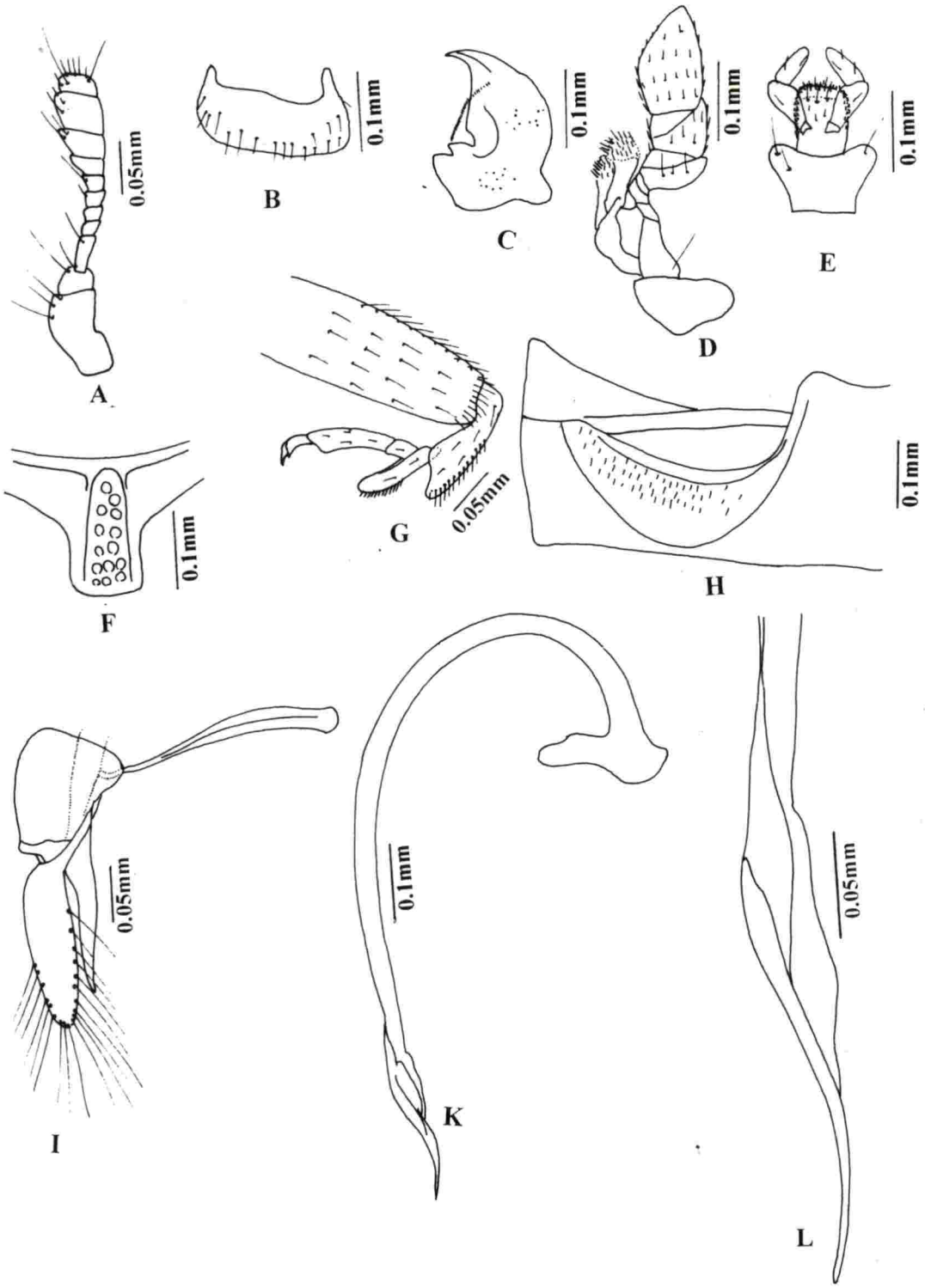


Fig. 27. *Scymnus* (*Pullus*) sp. 8

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; K. penis; L. penis apex

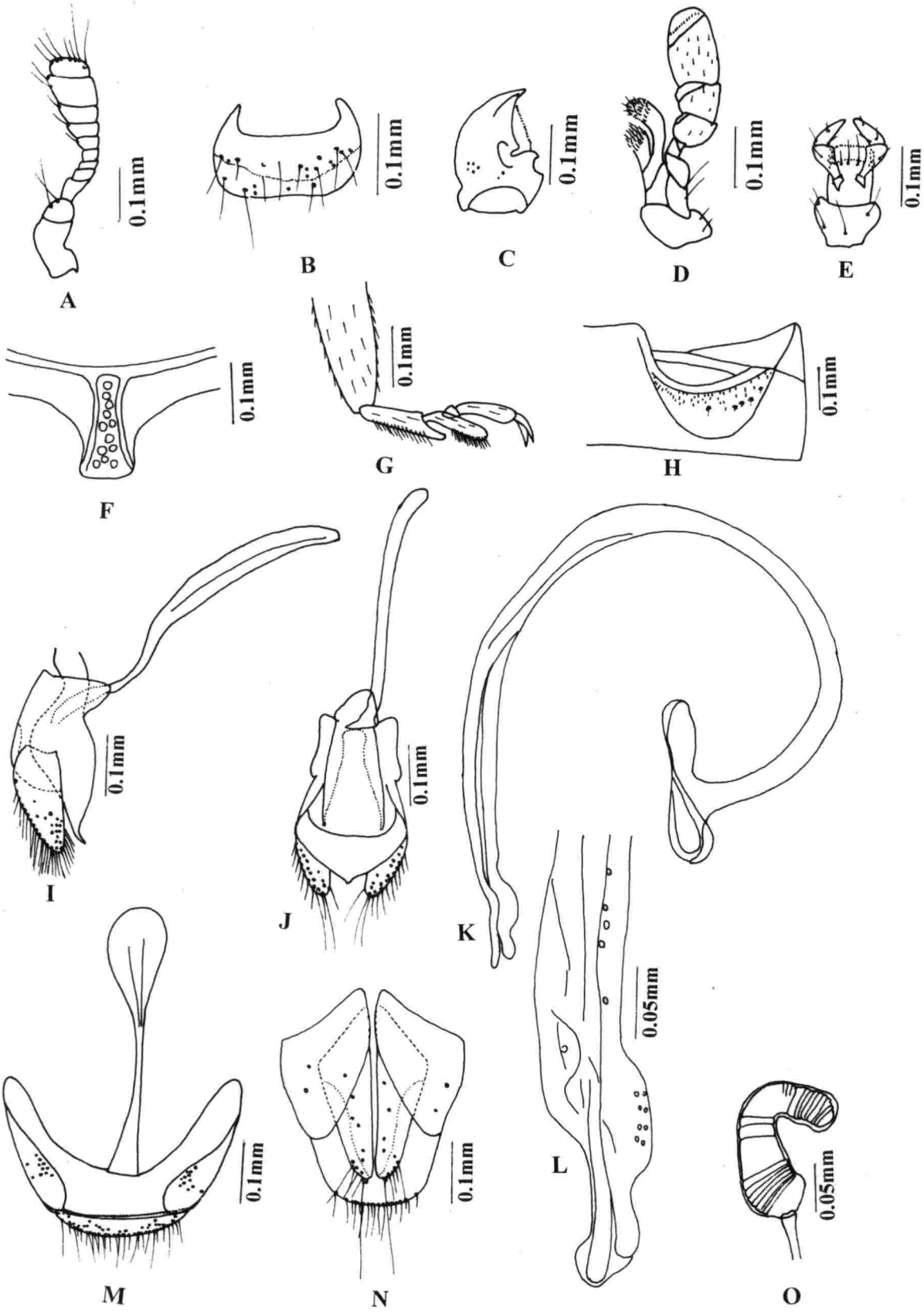


Fig. 28. *Scymnus* (*Pullus*) sp. 9

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex; M. genital segment of male; N. genital segment of female; O. spermatheca

yellowish or yellowish brown with darker pro-, meso- and metasternum and first abdominal ventrite; legs yellow to yellowish brown; antenna with 11 antennomeres, last four antennomeres are broader than rest of flagellar segments forming a club; terminal segment of maxillary palp nearly parallel sided; prosternal process with posteriorly diverging carina; post coxal line complete, area enclosed by lines sparsely punctate towards anterior and smooth along the postcoxal line.

Male genitalia: Tegmen stout with a prominent keel; parameres slightly longer than penis guide, apex with short setae of hairs; penis guide pointed at the apex and slightly curved in lateral view, penis guide widest at the middle and abruptly tapering towards a blunt apex in lateral view; penis stout with basal 2/3rd portion strongly curved, slightly narrowed at the beginning of curvature for a shorter length, remaining portion almost straight, apex of penis with two finger like blunt projection of subequal length, preapical region with a semicircular projection towards inner side; penis capsule with thin striation, inner arm narrow compared with broader outer arm.

Female genitalia: Hemisternites triangular; spermetheca bend at right angle at 2/5th length from distal end.

Measurements: Male: Total length: 1.58 (1.48-1.69) mm, total width: 1.18 (1.07-1.31) mm, TL/TW: 1.34 (1.29-1.38), PL/PW: 0.52 (0.51-0.53), EL/EW: 1.30 (1.09-1.41), EW/PW: 1.30 (1.27-1.39); **Female:** Total length: 1.59 (1.41-1.71) mm, total width: 1.18 (1.00-1.31) mm, TL/TW: 1.35 (1.29-1.47), PL/PW: 0.52 (0.47-0.60), EL/EW: 1.00 (0.86-1.11), EW/PW: 1.33 (1.25-1.43).

Material: India: Kerala: 2♂, 4♀, Vellanikkara, 03.ix.2015, 08.xii.2015 (VCV); 2♂, 1♀, Vazhakulam, 25.ii.2016 (VCV); 5♂, 8♀, Avinissery, 28.ii.2016, 13.iii.2016 (VCV); 1♀, Chalakkudy, 11.iii.2016 (VCV); 1♀, Pampadumpara, 30.iii.2016 (VCV); **Tamil Nadu:** 1♀, Maduri, 07.ix.2016 (VCV).

Prey/Associated host: *Dysmicoccus brevipes* and *Dysmicoccus neobrevipes* on pineapple; *Phenacoccus solenopsis* on *Hibiscus*; *Ferrisia virgata* on colocasia; mealybugs on mulberry; on hibiscus (prey not known).

Remarks: This species is unique among the species of Scymnini studied with prominent dorsal keel at the penis guide.

4. 1. 2. 1. 1. 6. 17. *Scymnus* (*Pullus*) sp. 10 (Plate 7d; Fig. 29)

Diagnostic characters: Body small, round oval, strongly convex, dorsum densely pubescent with silvery whitish hairs; head and mouth parts light brown; pronotum black with yellowish brown anterior and lateral area; scutellum black; elytra black with yellowish orange tip; ventral side black except prosternum and posterior part of abdomen; antenna with 11 antennomeres; terminal maxillary palpomere parallel; prosternal process with very weakly divergent carina; tarsi cryptotetramerous; post coxal line broadly curved, area enclosed by the line smoothly punctate along the the coxal line, rest area smooth.

Female genitalia: Genital plates trigonal, hemisternites triangular; spermatheca slender, finger like, bent at right angles medially.

Measurements: Total length: 1.90 mm, total width: 1.38 mm, TL/TW: 1.37, PL/PW: 0.47, EL/EW: 1.05, EW/PW: 1.27.

Material: India: Karnataka: 1♀, Dharwad, 17.ix.2016 (VCV); 2♀, Raichur, 23.ix.2016 (VCV); **Tamil Nadu:** 1♀, T. Kallupetti, 08.ix.2016 (VCV).

Prey/Associated host: *Phenacoccus solenopsis* on *Abutilon*; *Pseudococcus longispinus* on *Croton*; mealybugs on cotton, *Hibiscus*.

Subgenus *Scymnus* (*Scymnus*) Kugelann, 1794

Scymnus Kugelann, 1794: 545. Type species: designated by Westwood, 1838: 43, *Scymnus nigrinus* Kugelann, 1794.

Body small, oval, dorsum densely pubescent; antenna composed of 11 antennomeres; labrum transverse; mandibles bifid apically; terminal maxillary palpomere stout, weakly divergent; terminal palpomere of labial palp slightly shorter than preapical segment; prosternal carina distinct reaching the anterior margin of prosternum; tarsi cryptotetramerous; post coxal line of first abdominal ventrite incomplete, recurved forward basally, area surrounded by post coxal line coarsely punctate.

Remarks: *Scymnus* (*Scymnus*) is separated from *S.* (*Pullus*) with the shape of post coxal line on the first abdominal ventrite. Post coxal line is incomplete in subgenus *Scymnus* whereas complete in *Pullus*.

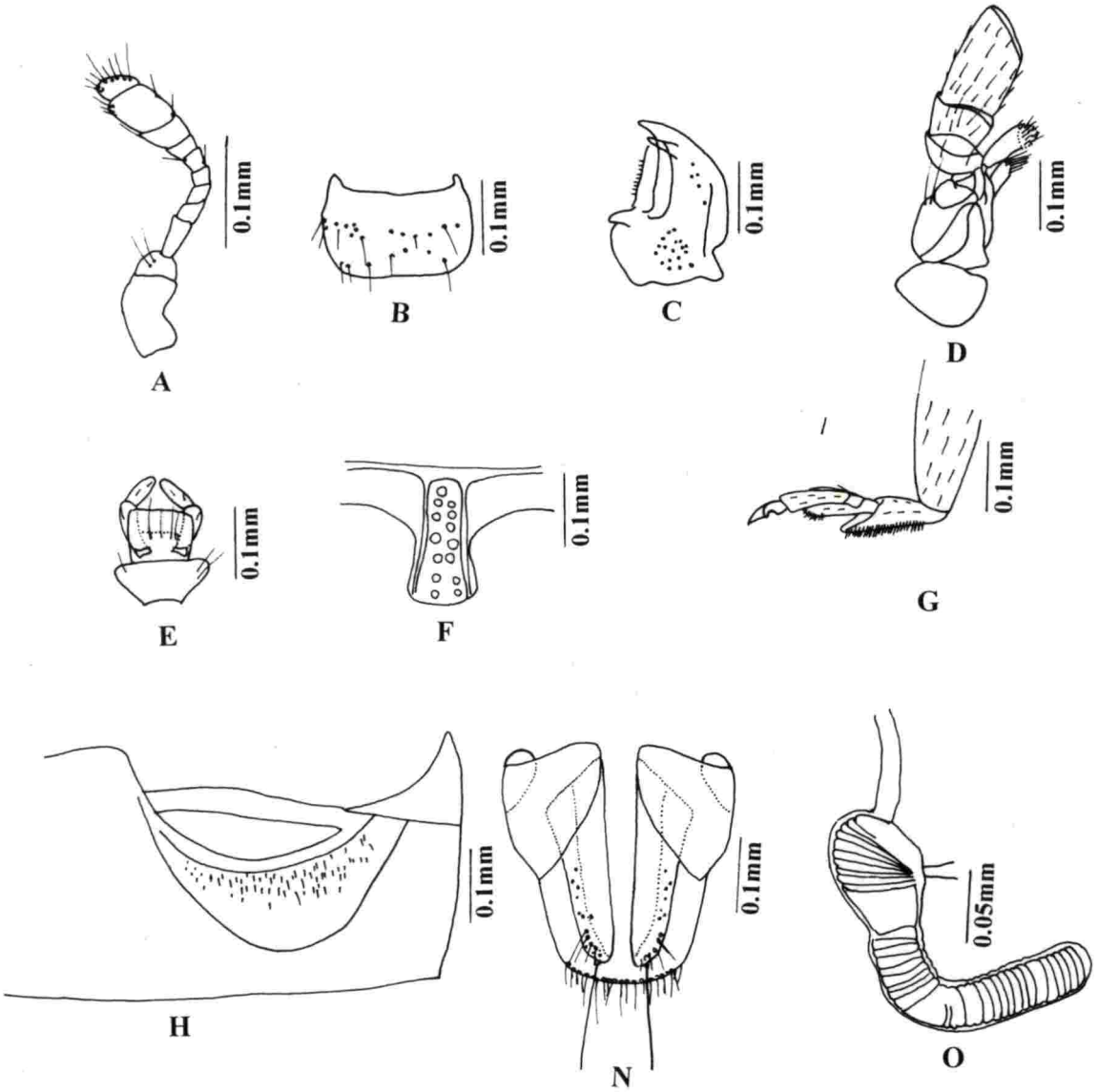


Fig. 29. *Scymnus* (*Pullus*) sp. 10

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; N. genital segment of female; O. spermatheca

4. 1. 2. 1. 1. 6. 18. *Scymnus* (*Scymnus*) *nubilus* Mulsant, 1850 (Plate 8a; Fig. 30)

Scymnus nubilus, Mulsant, 1850: 972. -Bielawski, 1972: 293. - Booth and Pope, 1989: 359.

Scymnus (Scymnus) nubilus: Korschefsky, 1931: 143 (cat.).

Scymnus curtisii Mulsant, 1850: 973. -Synonymised by Booth and Pope, 1989: 351.

Scymnus suturalis Motschulsky, 1858:120. -Crotch, 1874: 253. - Korschefsky, 1931: 144 (cat.). -Iablokoff-Khnzorian, 1972: 166.

Scymnus stabilis Motschulsky, 1866: 426. -Crotch, 1874: 257. - Weise, 1900: 439. – Korschefsky, 1931: 144 (cat.).

Scymnus lateralis Sicard, 1913: 502. -Korschefsky, 1931: 143 (cat). – Pang and Gordon, 1984: 133. – Synonymized by Booth and Pope, 1989: 360.

Diagnosis: Elytra reddish brown with a dark patch along the suture which is broadened at the base and narrowed towards the apex. Penis with wing like membraneous expansion towards distal region beyond 2/3rd length and penis apex is slightly broader with a short appendage.

Description: Body oblong oval; dorsum moderately convex, pubescent with whitish hairs; head and mouth parts yellowish to dark brown; pronotum dark brown to black in the middle, anterior margin and lateral sides reddish brown; scutellum dark brown; elytra reddish brown with a dark patch along the suture which is broadened at the base and narrowed towards the apex or narrowed towards the middle upto 1/3rd length of elytra and extends towards the apex with same width, the apical 1/5th portion of elytra without dark patch, lateral borders are narrowly dark brown to black at the middle; ventral side is yellowish brown to brown except pro-, meso- and metasternum and middle of abdominal segments dark brown; legs yellowish brown to dark brown; antenna with 11 antennomeres, last four segments are slightly broader than the rest flagellar segments; terminal maxillary palpomere nearly parallel sided; prosternal intercoxal process with posteriorly divergent carina; tarsi cryptotetramerous; post coxal line on first abdominal ventrite incomplete, area enclosed coarsely and densely punctate.

Male genitalia: Parameres with short hairs at the apex; slightly shorter than penis guide in lateral view; penis guide symmetrical, slightly bent towards the apex in

a. *Scymnus* (*Scymnus*) *nubilus*

b. *Scymnus saciformis*

c. *Scymnus* sp. 1

Plate 8. Species of Scymnini

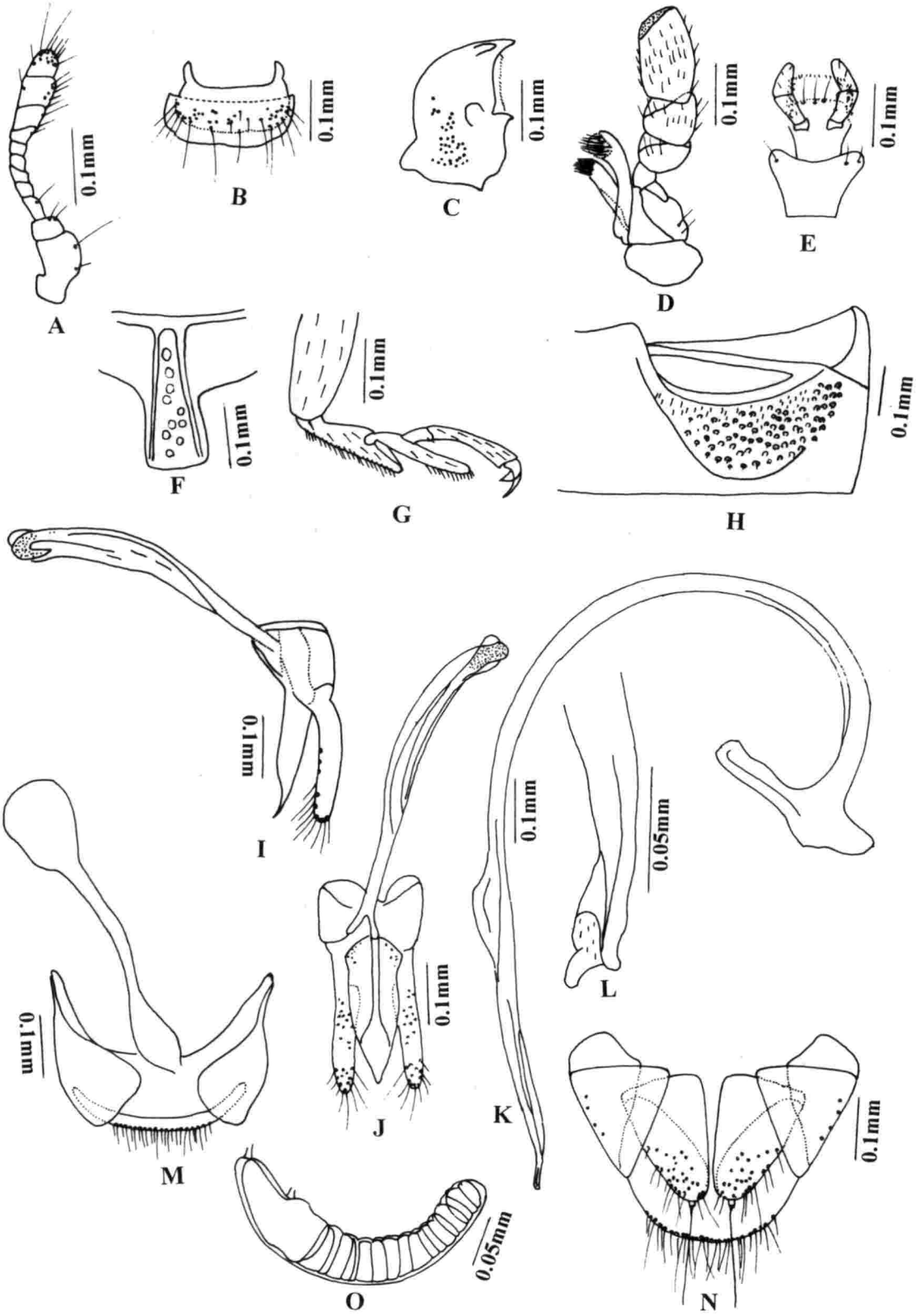


Fig. 30. *Scymnus* (*Scymnus*) *nubilus* Mulsant

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; J. tegmen, ventral; K. penis; L. penis apex; M. genital segment of male; N. genital segment of female; O. spermatheca

lateral view, trabes medially bent or curved; penis strongly curved on the basal half, straight towards the distal region with wing like membraneous expansion outside beyond 2/3rd length, apex of penis slightly broader with a short appendage, penis capsule with a long and narrow inner arm and short broad outer arm; apophysis of the ninth abdominal segment expanded distally.

Female genitalia: Genital plate broader; hemisternites triangular; spermatheca broadly curved.

Measurements: Male: Total length: 1.92 mm, total width: 1.38mm, TL/TW: 1.39, PL/PW: 0.56, EL/EW: 1.01, EW/PW: 1.40; **Female:** Total length: 2.04 mm, total width: 1.56 mm, TL/TW: 1.30, PL/PW: 0.51, EL/EW: 1.05, EW/PW: 1.45.

Material: India: Kerala: 1♀, Vellanikkara, 17.iii.2016 (VCV); **Tamil Nadu:** 1♀, Coimbatore, 14.viii.2015 (VCV); **Karnataka:** 2♂, 5♀, Dharwad, 16-17.ix.2016 (VCV); 4♂, 3♀, Raichur, 23.ix.16 (VCV).

Prey/Associated host: *Aphis craccivora* on *Gliricidia*, *Rhopalosiphum maidis* on maize, sorghum (prey not known).

Remarks: This species resemble to *Scymnus* (*Neopullus*) sp.1 in elytral pattern, but varies in the number of antennomeres and shape of post coxal line.

Species *incertae sedis*

In the present study, two species, *Scymnus saciformis* and *Scymnus* sp.2 distinctly vary from the characters of already described subgenera and hence the taxonomic position is uncertain. In these species, antenna is composed of 10 antennomeres, tarsi trimerous and post coxal line complete and sparsely punctate. These are different from subgenus *Neopullus* in the number of tarsomeres and nature of punctation in the area enclosed by abdominal post coxal line and different from *Scymnus* (*Pullus*) and *S.* (*Scymnus*) in the number of antennomeres and tarsomeres. Besides, abdominal post coxal line is incomplete in *Scymnus* (*Scymnus*). Hence these two species are treated separately.

4. 1. 2. 1. 1. 6. 19. *Scymnus saciformis*, 1858 (Plate 8b; Fig. 31)

Scymnus saciformis Motschulsky, 1858: 121.- Crotch, 1874: 255.- Weise, 1900: 438.

Scymnus (*Pullus*) *saciformis*: Korschefsky, 1931: 144 (cat.)

Diagnosis: Elytra black with a very narrow yellowish discolouration at the apical margin, parameres slender and penis apex dilated or broad at the apex.

Description: Body small, elongate oval, moderately convex, dorsum densely pubescent with white hairs; head yellow with yellowish mouth parts; pronotum yellow, sometimes a black colouration towards the posterior middle region of pronotum; scutellum black; ventral side yellow with darker prosternum and black meso- and metasternum, anterior part of abdomen black and posterior lighter; legs yellowish brown; antenna with 10 antennomeres, scape and pedicel not fused; terminal four antennomeres forming the antennal club; terminal maxillary palpomere strongly divergent; prosternal carina strongly divergent towards posteriorly; tarsi trimerous; post coxal line complete, broadly curved, area enclosed by line sparsely punctate, smooth at the middle and inner area near post coxal line.

Male genitalia: Parameres elongated, slender, bent at right angle at the base, a few small sized hairs at the apex; penis guide broad, both sides parallel upto 2/3rd length, then abruptly narrowed to apex, longer than paramers; trabes broad; penis stout, curved at the basal half, apex broad or dilated, penis capsule with long inner arm and outer arm almost lacking.

Female genitalia: Hemisternites triangular; spermatheca semicircular.

Measurements: Total length: 1.43 (1.38 - 1.48) mm, total width: 1.02 (0.96 – 1.10) mm, TL/TW: 1.40 (1.31 – 1.46), PL/PW: 0.52 (0.48 – 0.55), EL/EW: 1.04 (1.00 – 1.08), EW/PW: 1.24 (1.18 – 1.28).

Material: India: Kerala: 2♂, 5♀, Elavally, 07.ix.2015, 16.ix.2015 (VCV); 1♂, 4♀, Chembukkavu, 14.x.2015 (VCV); 5♂, 3♀, Vellanikkara, 08.xii.2015 (VCV); 2♂, 3♀, Avinissery, 28.ii.2016 (VCV); 3♂, 8♀, Kayakulam, 08.iii.2016 (VCV); 7♂, 12♀, Kumarakom, 14.iii.2016 (VCV); 2♂, 3♀, Vadakkenchery, 10.ii.2017 (VCV); 10♂,6♀, Banasura sagar, 10.iv.2017 (VCV); 13♂, 11♀, Ambalavayal, 12.iv.2017 (VCV); **Karnataka:** 1♂, Bengaluru, 23.ix.2017 (VCV); **Tamil Nadu:**

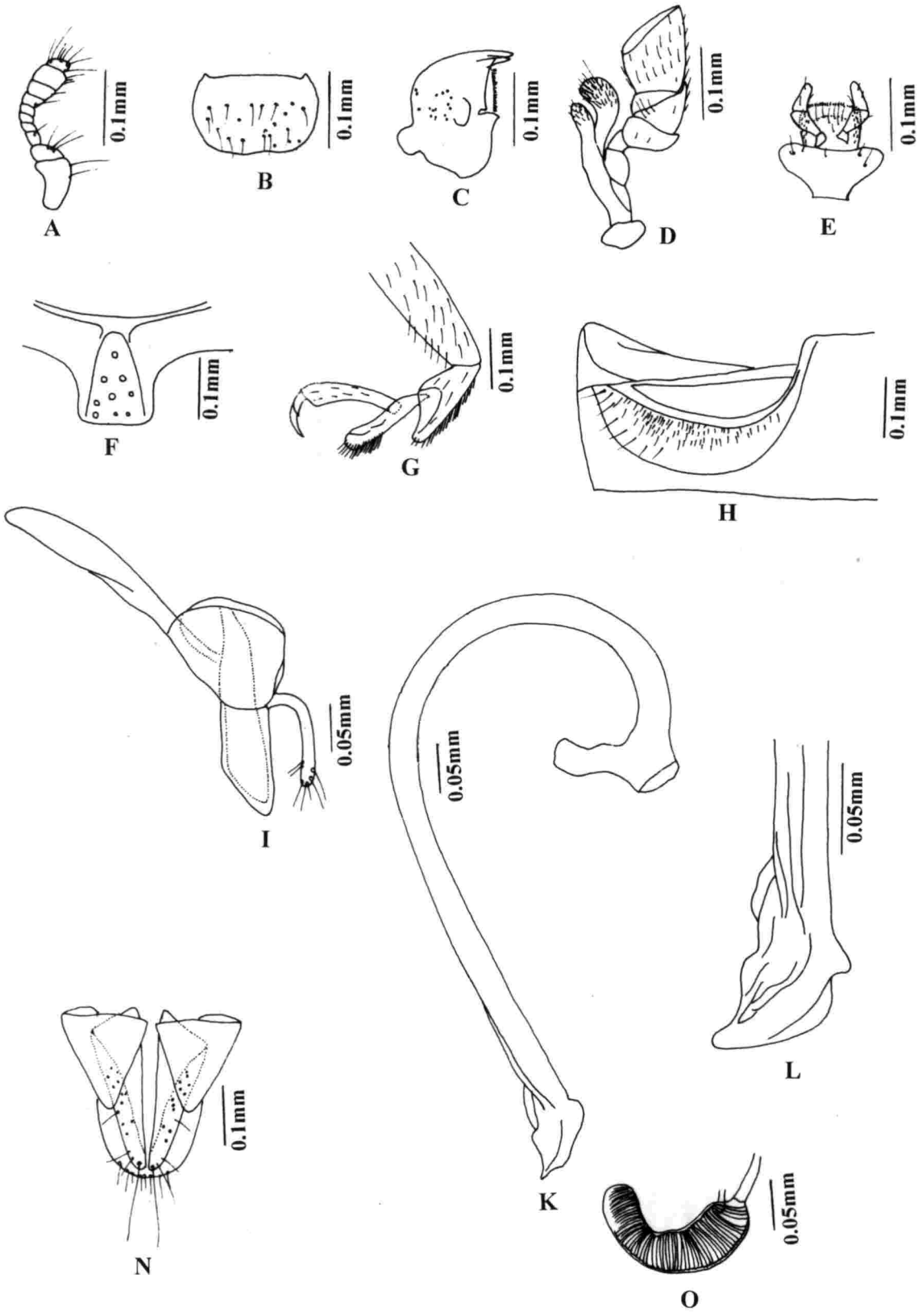


Fig. 31. *Scymnus saciformis* Motschulsky

A.antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; K. penis; L. penis apex; N. genital segment of female; O. spermatheca

2♂, 1♀, Coimbatore, 14.viii.2015 (VCV); 3♂, 1♀, T. Kallupetti, 08.ix.2016 (VCV); 5♂, 7♀, Madurai, 09.ix.2016 (VCV).

Prey/Associated host: *Coccidohystrix insolita* on brinjal; *Ferrisia virgata* on evergreen, tapioca; *Paracoccus marginatus* on mulberry, tapioca; *Phenacoccus solenopsis* on *Amaranthus*, *Hibiscus*; *Planococcus citri* on coffee; *Pseudococcus* sp. on coconut; mealybug on *Hibiscus*.

Remarks: *Scymnus saciformis* is separated from *S.* sp.2 with the shape of tegmen and penis apex. Tegmen of *S. saciformis* is shorter than penis guide, whereas penis guide is almost equal to parameres in *S.* sp. 2. Shape of penis apex also vary.

4. 1. 2. 1. 1. 6. 20. *Scymnus* sp. 1 (Plate 8c; Fig. 32)

Diagnosis: This species is identified by black elytra with apical 1/3rd yellow, parameres almost equal to penis guide and penis apex expanded with rounded outline.

Description: Body small, elongate oval, moderately convex, dorsum pubescent with dense hairs; head, mouth parts, pronotum and scutellum yellow; elytra black with apical 1/3rd region yellow; ventral side yellow with meso-and metasternum and anterior abdominal segments blackish or dark; antenna with 10 antennomeres, scape and pedicel not fused; terminal three antennomeres forming the antennal club; terminal maxillary palpomere weakly divergent; prosternal carina strongly divergent posteriorly; tarsi trimerous; post coxal line complete, broadly curved, area enclosed by line sparsely punctate, smooth at the middle and inner area near post coxal line.

Male genitalia: Parameres elongated, slender, bent at an angle at the base, a few small sized hairs at the apex; penis guide broad, both sides parallel upto 2/3rd length, then narrowed to apex, almost equal to parameres; trabes broad; penis stout, curved at the basal half, apex broad or dilated, penis capsule with long inner arm and broad outer arm.

Female genitalia: Hemisternites triangular; spermatheca semicircular.

Measurements: Total length: 1.84 mm, total width: 1.26 mm, TL/TW: 1.46, PL/PW: 0.54, EL/EW: 1.11, EW/PW: 1.34.

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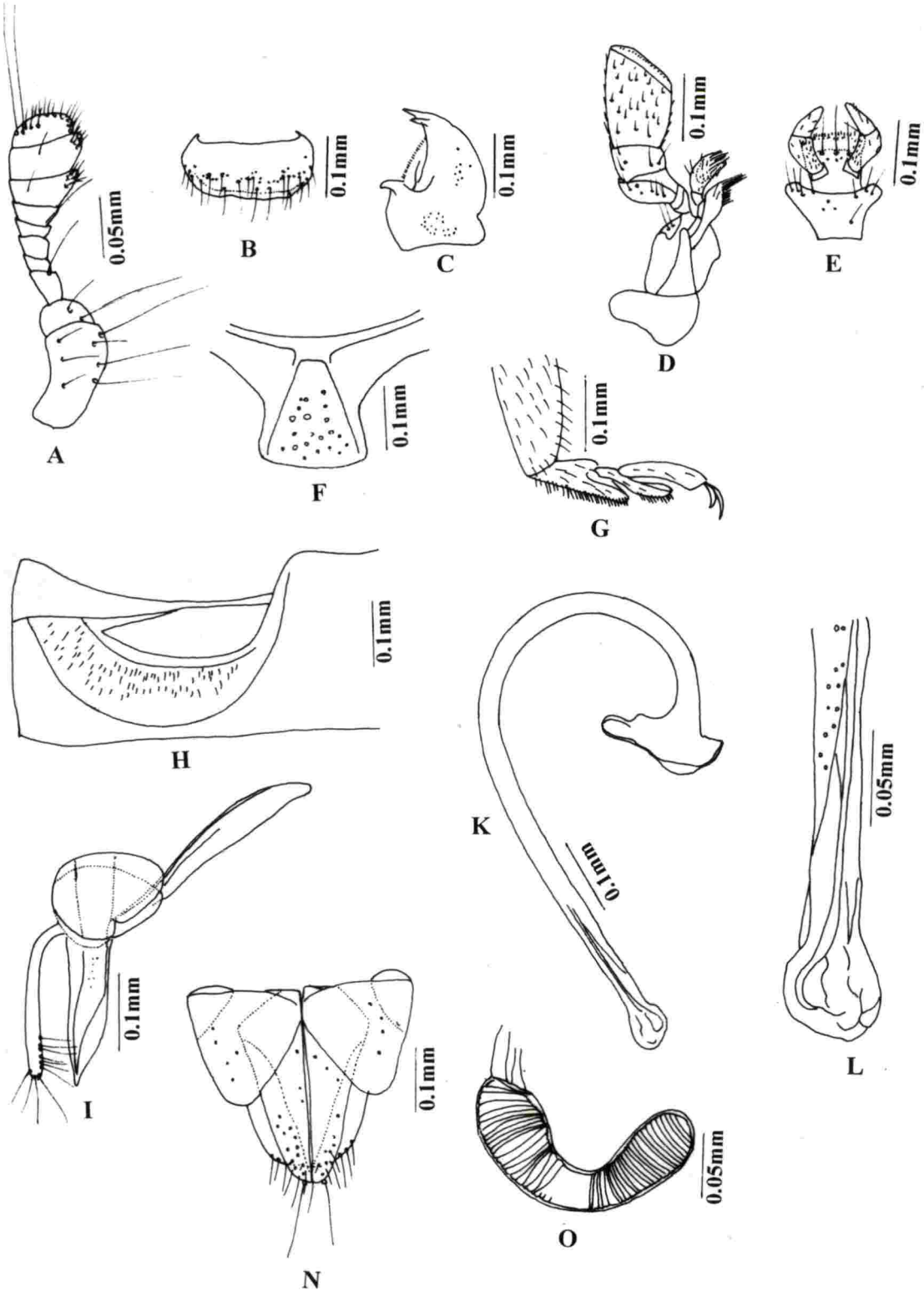


Fig. 32. *Scymnus* sp. 1

A.antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. prosternal process; G. hind tarsus; H. abdominal postcoxal line; I. tegmen, lateral; K. penis; L. penis apex; N. genital segment of female; O. spermatheca

Material: India: Kerala: 1♂, 2♀, Ambalavayal, 12.iv.2017 (VCV).

Prey/Associated host: *Planococcus citri* on coffee.

Remarks: The similarities of *Scymnus saciformis* and *S.* sp. 2 are discussed in the chapter 4. 1. 2. 1. 1. 6. 19.

4. 1. 2. 1. 2. Tribe Stethorini Dobzhansky, 1924

Stethorini Dobzhansky, 1924: 20.

Type genus: *Stethorus* Weise, 1885

Body very small, short oval to elongate oval, moderately to strongly convex, dorsum pubescent; body black, antennae, mouth parts and parts of legs yellowish or yellowish-testaceous; antenna with 10 to 11 antennomeres, not very short and with distinct club; terminal maxillary palpomere longer than wide, slightly convergent apically; anterior margin of prosternum roundly convex in the middle, partially concealing mouth parts; prosternal process without carina; elytral epipleura narrow, without foveae; legs simple, tarsi trimerous; metendosternite with broadly separated anterior tendons; abdomen with six visible ventrites; post coxal line of first abdominal ventrite complete or incomplete; tegmen of male genitalia usually slender, rarely stout; hemisternites of female elongate.

Ten species belonging to two genera were identified during the study which can be recognised with the following key.

Key to the genera of the tribe Stethorini collected during the study

1 Post coxal line of first abdominal ventrite incomplete; parameres with short, stout setae on inner side.....***Parastethorus*** Pang & Mao

_ Post coxal line of first abdominal ventrite complete, parameres without stout setae on inner inside.....***Stethorus*** Weise

4. 1. 2. 1. 2. 1. Genus *Parastethorus* Pang & Mao, 1975

Stethorus (*Parastethorus*) Pang & Mao, 1975: 294-304.

Type species: *Stethorus* (*Parastethrous*) *yunnanensis* Pang & Mao, 1975

Body very small, short oval, moderately convex, densely pubescent; body entirely black; antennae, mouth parts and parts of legs yellowish; prosternal carina absent; tarsi trimerous; elytal epipleura narrow, without any foveae; post coxal line of first abdominal ventrite incomplete; male genitalia with stout penis guide, parameres with many short stout setae on the inner side.

The one species recognised under this genus during the study is *P. indira*, which is the only species reported from India so far.

Remarks: Genus *Parastethorus* resembles *Stethorus* in external appearance, but can be differentiated with the incomplete abdominal post coxal line. Besides many short, stout setae like process are present on the inner side of parameres.

4. 1. 2. 1. 2. 1. 1. *Parastethorus indira* (Kapur) (Plate 9a; Fig. 33)

Stethorus indira Kapur, 1950: 148.

Stethorus (*Parastethorus*) *indira*: Yu, 1996: 33.

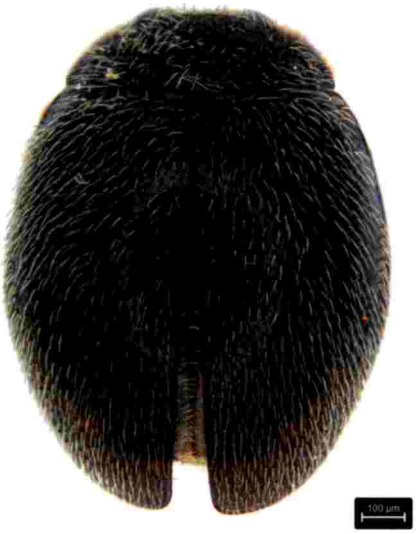
Stethorus (*Parastethorus*) *guangxiensis* Pang & Mao, 1979: 39.- Synonymised by Poorani, 2004: 186.

Parastethorus indira (Kapur): Li *et al.*, 2015: 125.

Diagnosis: This species is characterised by broad penis guide with a notch at the apex in the ventral view and tubular penis.

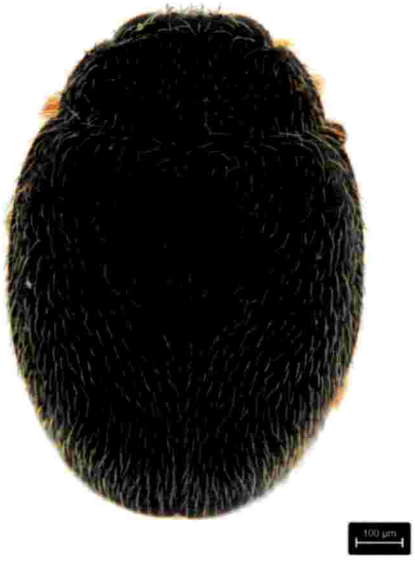
Description: Body very small, shortly oval, moderately convex, dorsum with silvery suberect greyish white pubescence; head, pronotum, elytra and ventral side black, antennae and mouth parts yellowish, legs yellow; antenna with 11 antennomeres, terminal four antennomeres forming the club; terminal maxillary palpomere weakly convergent; post coxal line of first abdominal ventrite incomplete not reaching the base of abdominal ventrite, post coxal line extending $3/4^{th}$ of the length of first abdominal ventrite, area surrounded by the line with a few smooth and sparse punctures; sixth abdominal ventrite of males weakly truncate at the posterior margin.

Male genitalia: Tegmen stout; parameres stout, elongated oval, shorter than penis guide, reaching $>2/3^{rd}$ length of penis guide, with many short stout setae in the inner region and a few long hairs on the apical region and also inner margin; in lateral



a. *Parastethorus indira*

b. *Stethorus* (*Allostethorus*) *forficatus*



c. *Stethorus* (*Allostethorus*) *pauperculus*

d. *Stethorus* (*Allostethorus*) *tetranychi*

Plate 9. Species of Stethorini

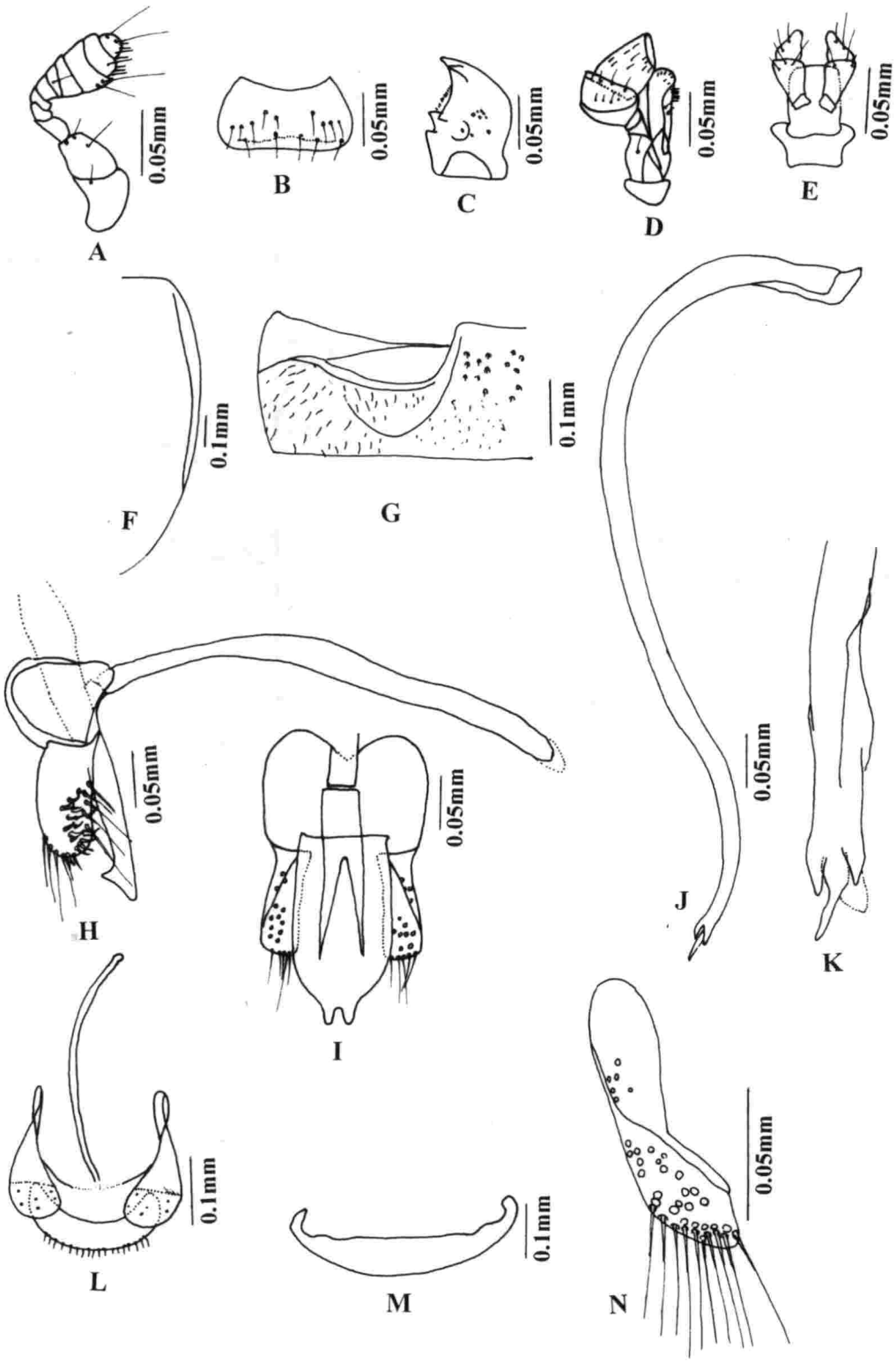


Fig. 33. *Parastethorus indira* (Kapur)

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. elytral epipleuron; G. abdominal postcoxal line;; H. tegmen, lateral; I. tegmen, ventral; J. penis; K. penis apex; L. genital segment of male; M. sixth abdominal ventrite of male; N. hemisternite

view, margins of penis guide run parallel till the preapical region, thereafter both margins join which gives a triangular appearance to the apex, in ventral view, penis guide is broad, both margins runs parallel upto 3/4th length, then join forming a notch at the apex; trabes fairly long and dark; penis tubular with its base and apical region gently cuved, penis capsule short; ninth abdominal segment with well sclerotized, long, slender apophysis without any dilation distally.

Female genitalia: Hemisternite spatulate with a constriction in the middle, a number of long setae towards apical margin.

Measurements: Measurements: Total length: 1.16 (1.07 - 1.29) mm, total width: 0.86 (0.82 - 0.99) mm, TL/TW: 1.33 (1.30 - 1.46), PL/PW: 0.46 (0.40 - 0.50), EL/EW: 1.06 (0.98 - 1.18), EW/PW: 1.35 (1.25 - 1.39).

Material: India: Kerala: 3unsexed, Marakkal, 20.ii.2016 (VCV); 2unsexed, Ambalavayal, 25.ii.2016 (VCV); unsexed Olarikkara, 12.iii.2017 (VCV); **Tamil Nadu:** unsexed, Madathukulam, 12.iv.2016 (VCV).

Prey/Associated host: *Eutetranychus orientalis* (Klein) on castor, plumeria; on coconut, cassia (prey not known)

4. 1. 2. 1. 2. 2. Genus *Stethorus* Weise, 1885

Scymnus (*Stethorus*) Weise, 1885: 65.

Stethorus Weise, 1899: 64.-Kapur, 1948: 297. Type species: *Coccinella minimus* Rossi, 1794 (= *Stethorus punctillum* Weise, 1891)

Nephopullus Brethes, 1925: 167.-Kapur, 1948: 300. Type species: *Nephopullus darwini* Brethes

Body very small, short oval to elongate oval, moderately to strongly convex, densely pubescent; body entirely black; antenna, mouth parts and parts of legs yellowish or yellowish-testaceous; prosternal carina absent; elytal epipleura narrow, nearly horizontal without any foveae; male genitalia with slender or stout penis.

Remarks: Similarity of *Stethorus* with *Parastethorus* is discussed in Chapter 4. 1. 2. 1. 2. 1.

Key to the subgenera and species of the genus *Stethorus* collected during the study

1 Antenna with 10 antennomeres; male genitalia lacking trabes (Fig. 42H); spermatheca globose (Fig. 42O)……..……***Stethorus keralicus*** Kapur

_ Antenna with 11 antennomeres; male genitalia with trabes (Fig. 35H); spermatheca varied……..……..……..……...2

2(1) Male genitalia with short penis (Fig. 34J), stout penis guide, tegminal strut almost equal to penis guide (34H)……..…….. ……***Stethorus*** (***Allostethorus***) Iablokoff-Khnzorian.....3

_ Male genitalia with slender penis (Fig. 40J) and tegminal strut shorter than penis guide (40H)……..…***Stethorus*** (***Stethorus***) Weise……...…..6

3(2) Penis guide bifurcated apically (Fig. 34I) ……..……...4

_ Penis guide not bifurcated (Fig. 35I)……..5

4(3) Post coxal line of first abdominal ventrite, broadly V-shaped, deep, extending 3/4th length of first abdominal ventrite; two prongs of penis guide not so elongated; parameres distinctly longer than penis guide with short apical hairs (Fig. 34I)..***Stethorus*** (***Allostethorus***)***forficatus*** Poorani

_ Post coxal line of first abdominal ventrite broadly V-shaped, but not deep, extending 2/3rd length of first abdominal ventrite; two prongs of penis guide elongated and pointed; parameres almost equal to penis guide with medium long hairs on the lateral side and inner margin (Fig. 36I)……***Stethorus*** (***Allostethorus***) ***tetranychi*** Kapur

5(3) Penis guide subtriangular (Fig. 35I); penis capsule short, inner arm much shorter than outer arm; penis bent at an obtuse angle in the apical 1/6th length (Fig. 35J) ……***Stethorus*** (***Allostethorus***) ***pauperculus*** (Weise)

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_ Penis guide elongate oval (Fig. 37I); penis capsule with equal sized inner and outer arm; penis abruptly narrowed in the apical 1/4th length (Fig. 37J)..... ***Stethorus* (*Allostethorus*) sp. 1**

6(2) Post coxal line of first abdominal ventrite semicircular (Fig. 39G); male genitalia bearing a polyfurcate hair process at the apex of parameres (Fig. 39H); penis thread like at the apical end (39J).....7

_ Post coxal line of first abdominal ventrite not semicircular (Fig. 40G); male genitalia without polyfurcate hair process at the apex of parameres (Fig. 40H); penis tubular (Fig. 40J) 8

7(6) Penis irregularly curved (Fig. 38J); penis guide tapering towards apex which is slightly bent towards the parameres (Fig. 38H); last visible abdominal ventrite of male more or less truncate at the apical margin (Fig. 38M) .....***Stethorus (Stethorus) rani*** Kapur

_ Penis looped at the basal 2/3rd length (Fig. 39J); penis guide not gradually tapering towards the apex, apex not bent towards parameres (Fig. 39H); last visible abdominal ventrite of male emarginate at the apical margin (Fig. 39M) .....***Stethorus* (*Stethorus*) sp. 1**

8(6) Tegmen bent towards the base; parameres slender with single long setae at the apex (Fig. 40H); last abdominal ventrite of male distinctly emarginate at the apical margin (Fig. 40M)..... ***S.* (*Stethorus*) sp. 2**

_ Tegmen almost straight towards base; parameres relatively broader, with a few setae at the apex (Fig. 41H); last abdominal ventrite of male weakly emarginate at the apical margin (Fig. 41M) .....***S.* (*Stethorus*) sp. 3**

Subgenus *Stethorus* (*Allostethorus*) Iablokoff-Khnzorian, 1972

Stethorus (*Allostethorus*) Iablokoff-Khnzorian, 1972: 120.

Type species: *Stethorus* (*Allostethorus*) *amurensis* Iablokoff-Khnzorian, 1972, by original designation.

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Body short oval to elongate oval, moderately convex, densely pubescent; black coloured with antennae and mouth parts yellowish or yellowish brown; legs completely or partly yellowish; antenna with 11 antennomeres; terminal maxillary palpomere slightly convergent; prosternal carina absent; tarsi trimerous; post coxal line of first abdominal ventrite complete; male genitalia with short penis, stout penis guide, tegminal strut longer or almost equal to penis guide.

Remarks: Subgenus *Allostethorus* can be separated from subgenus *Stethorus* by short penis, stout penis guide and tegminal strut almost equal to penis guide. In subgenus *Stethorus* penis is slender with tegminal strut much shorter than penis guide.

Two subgenera have been described under this genus *viz.*, *Stethorus* (*Allostethorus*) and *Stethorus* (*Stethorus*) with four species in each genus.

4. 1. 2. 1. 2. 2. 1. *Stethorus* (*Allostethorus*) *forficatus* Poorani, 2017 (Plate 9b; Fig. 34)

Stethorus (*Allostethorus*) *forficatus* Poorani, 2017: 593

Diagnosis: This species is distinguished by the following characters: post coxal line of first abdominal ventrite, broadly V-shaped, deep, extending 3/4th length of first abdominal ventrite, penis guide bifurcated and fork shaped in the ventral view and two prongs of penis guide widely apart and distinctly shorter than parameres.

Description: Body small, oval, fairly convex, dorsum with dense silvery white pubescence; head, pronotum, elytra and ventral side black, antennae and mouth parts yellowish, legs yellow except coxae; antenna with 11 antennomeres, width of terminal segments broadened gradually; terminal palpomere of maxillary palp slightly convergent; post coxal line of first abdominal ventrite complete, deep, broadly V-shaped, extending 3/4th length of the ventrite, area enclosed by the line with a few smooth punctures, sparsely arranged, mainly confined to anterior half; sixth abdominal ventrite of males truncate at the posterior margin.

Male genitalia: Tegmen stout; parameres broadest at base, gradually narrowed towards blunt apex, inner lateral margin and apex with a few short hairs; penis guide

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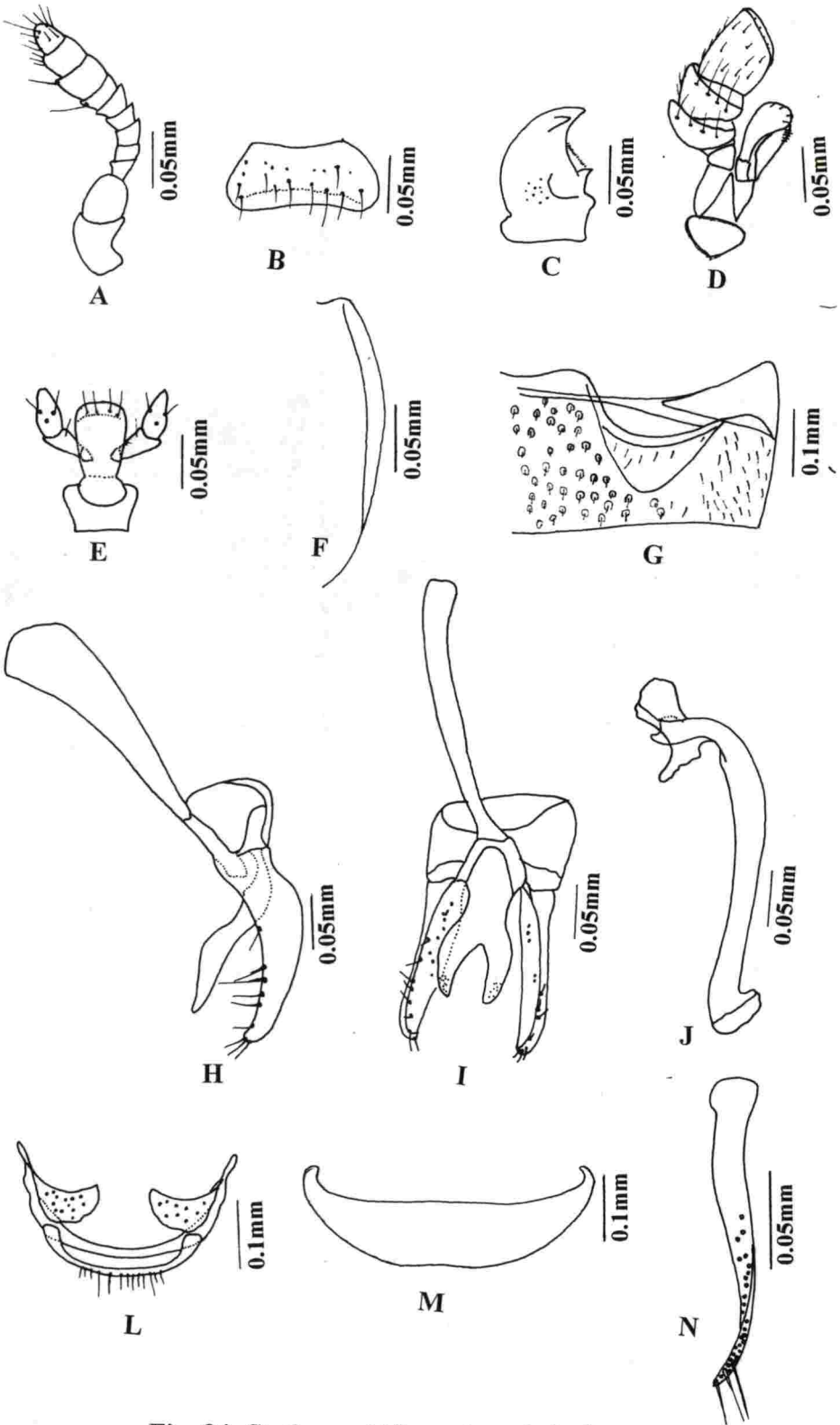

Fig. 34. *Stethorus* (*Allostethorus*) *forficatus* Poorani

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. elytral epipleuron; G. abdominal postcoxal line;; H. tegmen, lateral; I. tegmen, ventral; J. penis; L. genital segment of male; M. sixth abdominal ventrite of male; N. hemisternite

bifurcated, pincer-like or fork shaped in the ventral view and distinctly shorter than parameres, two prongs of penis guide widely apart; penis short, stout, curved near to penis capsule with a constriction, penis capsule well defined with broad short inner and outer arm; penis apex slightly curved, broad.

Female genitalia: Hemisternite narrow, elongated with broad base, narrow apex, apex densely punctate, a few medium long hairs at the apical region; spermatheca absent.

Measurements: Total length: 1.17 (1.10 - 1.26) mm, total width: 0.89 (0.82 - 0.96) mm, TL/TW: 1.31 (1.25 - 1.38), PL/PW: 0.49 (0.44 - 0.54), EL/EW: 1.05 (0.97 - 1.10), EW/PW: 1.35 (1.31 - 1.43).

Material: India: Kerala: 14unsexed, Tavanur, 11.xii.2015 (VCV); unsexed, Padannakkad, 20.xii.2015 (VCV); 11unsexed, Vellanikkara, 18.i.2016, 25.ii.2016, 02.iii.2016 (VCV); 4unsexed, Kayamkulam 08.iii.2016 (VCV); 7unsexed, Payyanam, 23.iii.2016 (VCV); 6unsexed, Vellayani, 20.iv.2016 (VCV); **Karnataka:** 2unsexed, Bengaluru, 25.xii.2015 (VCV); **Tamil Nadu:** 4sexed, Coimbatore, 14.viii..2015 (VCV); 8unsexed, Madurai, 07.ix.2016 (VCV).

Prey/Associated host: *Tetranychus truncatus* Ehara on *Amaranthus*, *Cosmos*, cowpea, papaya, tapioca; *T. okinawanus* Ehara on cowpea; jack, mulberry (prey not known).

Remarks: *Stethorus* (*Allostethorus*) *forficatus* resembles to *S.* (*A.*) *tetranychi* by the presence of bifid penis guide, but can be separated with tegmen with parameres longer than penis guide. The shape of the prong of penis guide also vary.

4. 1. 2. 1. 2. 2. 2. *Stethorus* (*Allostethorus*) *pauperculus* (Weise), 1895 (Plate 9c; Fig. 35)

Scymnus (*Stethorus*) *pauperculus* Weise, 1895: 155.

Stethorus pauperculus: Weise, 1900: 440.-Kapur, 1948: 309.

Diagnosis: This species is identified by the presence of subtriangular penis guide and stout penis which is bent at an obtuse angle in the apical 1/6th length.

Description: Body small, elongate oval, moderately convex, dorsum densely pubescent with greyish white hairs; body black except antennae and mouth parts

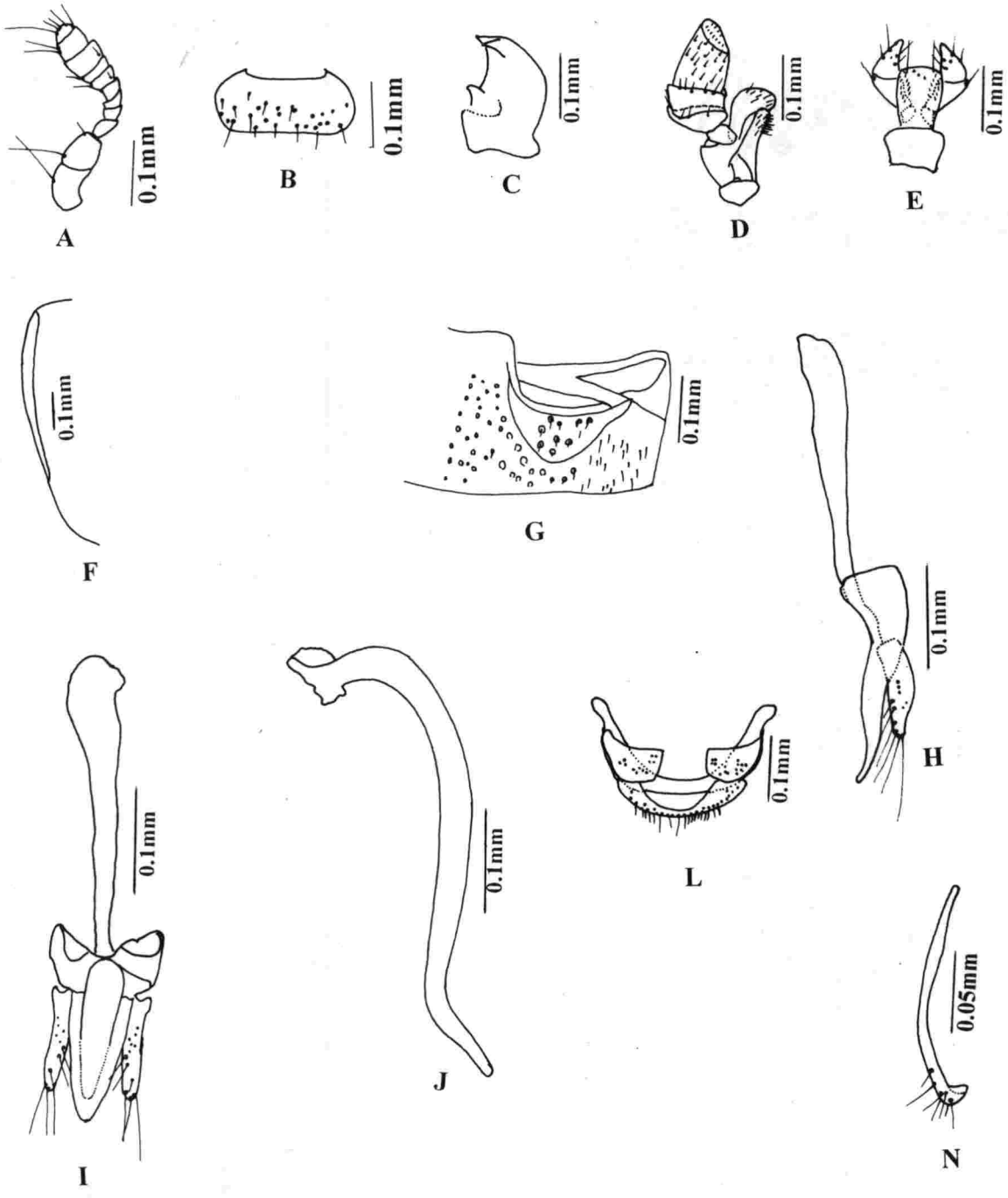

Fig. 35. *Stethorus* (*Allostethorus*) *pauperculus* (Weise)

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. elytral epipleuron; G. abdominal postcoxal line;; H. tegmen, lateral; I. tegmen, ventral; J. penis; L. genital segment of male; N. hemisternite

yellow, legs yellow with parts of femora reddish brown; antenna composed of 11 antennomeres, 5th to 11th antennomere forming the club; terminal maxillary palpomere slightly convergent; post coxal line of first abdominal ventrite complete, narrowly semicircular, extending 2/3rd of abdominal ventrite, area enclosed by the line with a few moderately coarse punctures mainly confined towards middle; sixth abdominal ventrite without any emargination in posterior margin in males.

Male genitalia: Tegmen stout with a wide phallobase; parameres shorter than penis guide with a number of relatively long setae in the apical half; penis guide subtriangular, widest at the base, nearly parallel more than 1/3rd length, and then gradually converged to a blunt apex in ventral view; trabes long, dilated at the distal end; penis stout and short, moderately curved at basal 1/6th length, apical 1/6th length bent at an obtuse angle in opposite direction, penis capsule short, broad, outer arm semicircular, inner arm short.

Female genitalia: Hemisternites narrow, elongated, a few short hairs in the apical region; spermatheca lacking.

Measurements: Male: Total length: 1.03 (0.90 - 1.12) mm, total width: 0.73 (0.62 - 0.83) mm.

Material: India: Kerala: 6unsexed, Avinissey, 03.v.2015 (VCV); 9unsexed, Vadakkenchery, 09.xii.2015 (VCV); 6unsexed, Padannakkad, 20.xii.2015 (VCV); 3unsexed, Marakkal, 20.ii.2016 (VCV); 3unsexed, Ambalavayal, 25.ii.2016 (VCV); 2unsexed, Mukkam, 05.iii.2016 (VCV); 26unsexed, Kayamkulam, 08.iii.2016 (VCV); 6unsexed, Chalakkudy, 11.iii.2016 (VCV); 7unsexed, Kumarakom, 14.iii.2016 (VCV); 4unsexed, Vellanikkara, 17.iii.2016 (VCV); 9unsexed, Vellayani, 20.iiv.2016 (VCV); 14unsexed, Sreekaryam, 21.iv.2016 (VCV); **Karnataka:** 2unsexed, Hiriyur, 02.vii.2014 (SN); 2unsexed, Mandya, 03.vii.2014 (CCG); 6unsexed, Bengaluru, 04.vii.2014 (SN); 6unsexed, Bengaluru, 16.vii.2015 (SN); 6unsexed, Bengaluru, 16.vii.2015 (SN); 8unsexed, Shivamogga, 06.iv.2016 (VCV); 18unsexed, Raichur, 22.ix.2016, 23.ix.2016 (VCV); **Tamil Nadu:** 5unsexed, Coimbatore, 14.viii.2015 (VCV); 4unsexed, Madurai, 07.ix.2016 (VCV).

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Prey/Associated host: *Oligonychus indicus* (Hirst) on bajra, maize, sorghum; *Oligonychus* sp. on arecanut, banana; *Tetranychus truncatus* on bhindi, cowpea; *T. macfarlanei* Baker and Pritchard on *Amaranthus*; *T. okinawanus* on cowpea; *Tetranychus* sp. on bhindi; on banana, bhindi, coconut, ridge gourd, soyabean, sugarcane (prey not known).

Remarks: *Stethorus* (*Allostethorus*) *pauperculus* looks similar to *S.* (*A.*) sp. 1, but the two species vary in the shape of penis guide, penis capsule and penis apex.

4. 1. 2. 1. 2. 2. 3. *Stethorus* (*Allostethorus*) *tetranychi* Kapur, 1948 (Plate 9d & Fig 36)

Stethorus tetranychi Kapur, 1948: 311.

Stethorus (*Allostethorus*) *tetranychi*: Poorani, 2017: 595

Diagnosis: This species is distinguished by the following characters: post coxal line of first abdominal ventrite broadly V-shaped, extending 2/3rd length of first abdominal ventrite; penis guide bifurcated, parameres almost equal to penis guide with medium long hairs on the lateral side and inner margin.

Description: Body small, broadly oval, moderately convex, dorsum with dense silvery white pubescence; head, pronotum, elytra and ventral side black and antennae, mouth parts and legs yellow; antenna with 11 antennomeres, antennal club well distinct; terminal maxillary palpomere slightly convergent; post coxal line of first abdominal ventrite complete, broadly V-shaped, extending 2/3rd of abdominal ventrite, area enclosed by the line with a few smooth and sparsely arranged punctures; sixth abdominal ventrite of males weakly emarginate at the posterior margin.

Male genitalia: Tegmen moderately stout; parameres broad at base, narrowed at the middle, apex rounded with a few medium long setae, slightly shorter than penis guide in lateral view; penis guide bifurcated from the apex to more than half of its length, the two prongs are not widely apart; penis short, stout, gently curved at the basal part, penis apex bent towards opposite direction and acute; ninth abdominal segment with well sclerotized, short, slender apophysis without any dilation distally.

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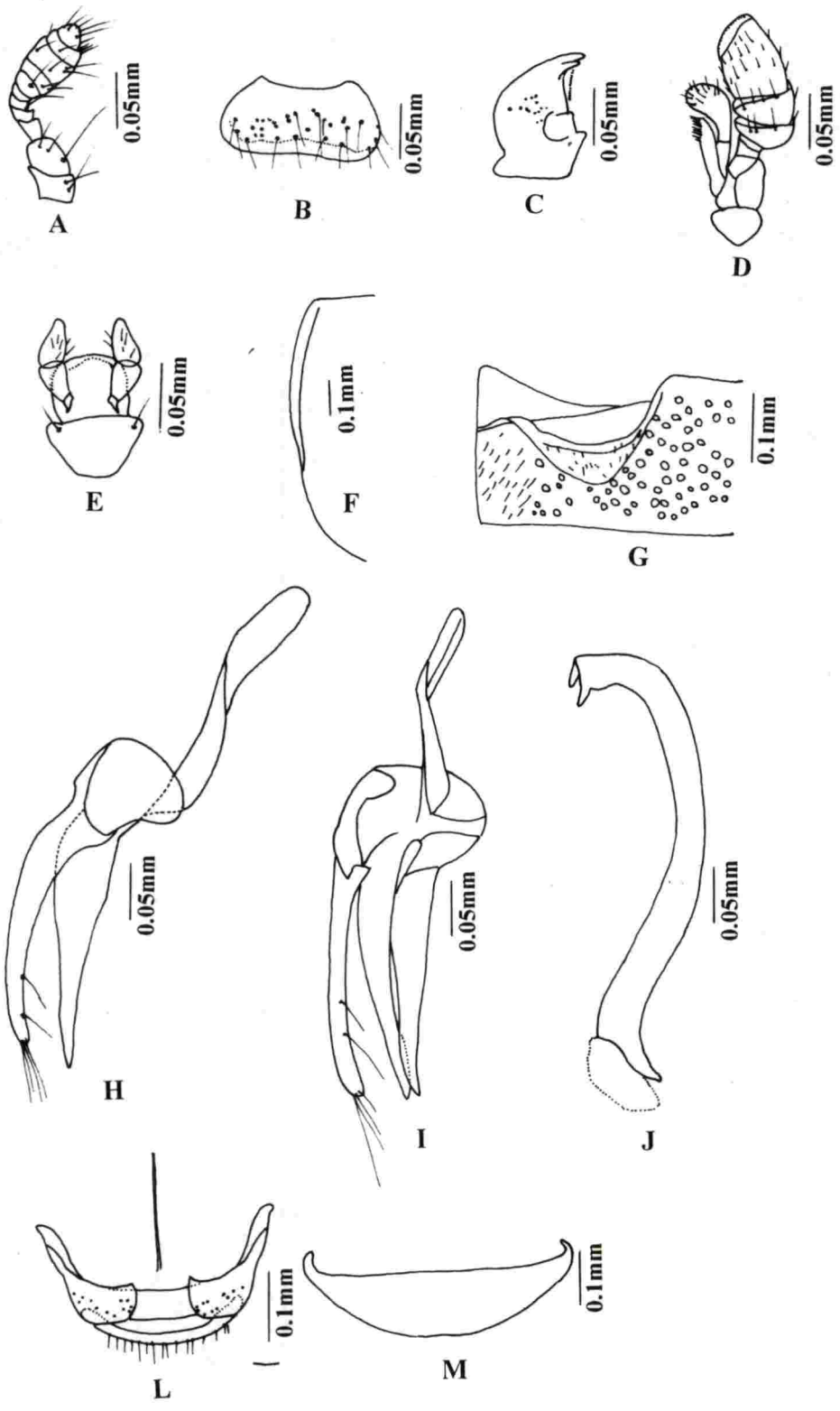


Fig. 36. *Stethorus* (*Allostethorus*) *tetranychi* Kapur

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. elytral epipleuron; G. abdominal postcoxal line; H. tegmen, lateral; I. tegmen, ventral; J. penis; L. genital segment of male; M. sixth abdominal ventrite of male

Measurements: Total length: 1.28 (1.26 - 1.31) mm, total width: 0.94 (0.86 - 0.96) mm, TL/TW: 1.35 (1.33 - 1.51), PL/PW: 0.48 (0.44 - 0.50), EL/EW: 1.06 (1.05 - 1.07), EW/PW: 1.34 (1.33 - 1.36).

Material: India: Kerala: 2unsexed, Marakkal, 20.ii.2016 (VCV); 5unsexed, Ambalavayal, 25.ii.2016 (VCV); **Karnataka:** 6unsexed, Bengaluru, 25.xii.2015 (VCV); **Tamil Nadu:** 1unsexed, Tiruchirappalli, 25.ii.2016 (VCV).

Prey/Associated host: *Tetranychus* sp. on coconut; on bauhinia, coconut, *Helecteres isora* (prey not known).

Remarks: Resemblance of this species with *Stethorus* (*Allostethorus*) *forficatus* is discussed in 4. 1. 2. 1. 2. 2. 1.

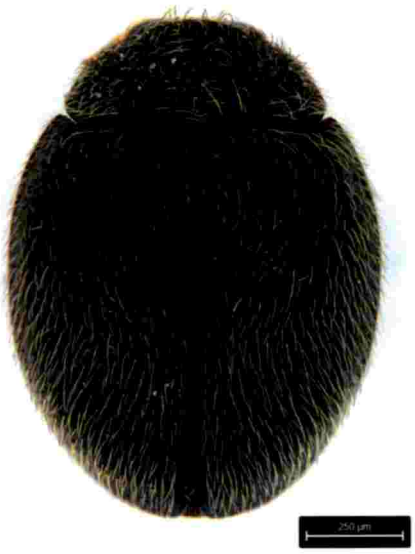
4. 1. 2. 1. 2. 2. 4. *Stethorus* (*Allostethorus*) sp. 1 (Plate 10a & Fig. 37)

Diagnosis: This species is identified by the presence of elongate oval penis guide and stout penis which is abruptly narrowed at the apical 1/4th length and penis capsule with equal sized inner and outer arm.

Description: Body small, oval, moderately convex, dorsum with dense silvery white pubescence; head, pronotum, elytra and ventral side black, antennae and mouth parts yellowish, legs yellow except black coxae; antenna with 11 antennomeres, terminal four antennomeres forming club; terminal maxillary palpomere slightly convergent; post coxal line of first abdominal ventrite complete, not deeply rounded, extending more than half the length of abdominal ventrite, area enclosed by the line with relatively coarse and sparse punctures; sixth abdominal ventrite of males weakly emarginate at the posterior margin.

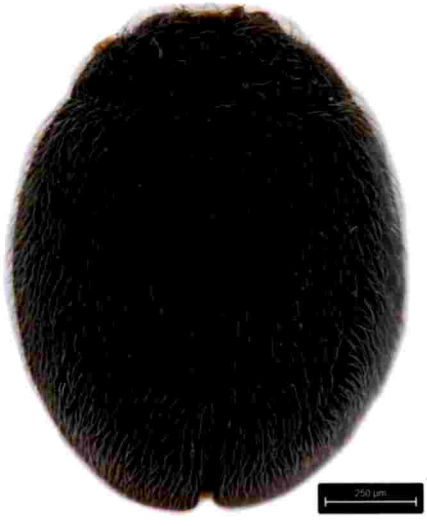
Male genitalia: Tegmen stout; parameres broad at base, gradually narrowed towards round apex, inner lateral margin of apical half with a few short hairs and apex with a few medium long hairs; penis guide elongate in lateral view, slightly longer than parameres with a narrow blunt apex;, penis guide elongate oval in ventral view, margins parallel upto 2/3rd of length, apical region curved; trabes long and dilated distally; penis characteristically curved, proximal 1/4th length gently curved, and apical 1/4th length abruptly narrowed to a an elongated apex; penis capsule with equal sized inner and outer arm.

a. *Stethorus* (*Allostethorus*) sp. 1



b. *Stethorus* (*Stethorus*) *rani*

c. *Stethorus* (*Stethorus*) sp. 1



d. *Stethorus* (*Stethorus*) sp. 2

Plate 10. Species of Stethorini

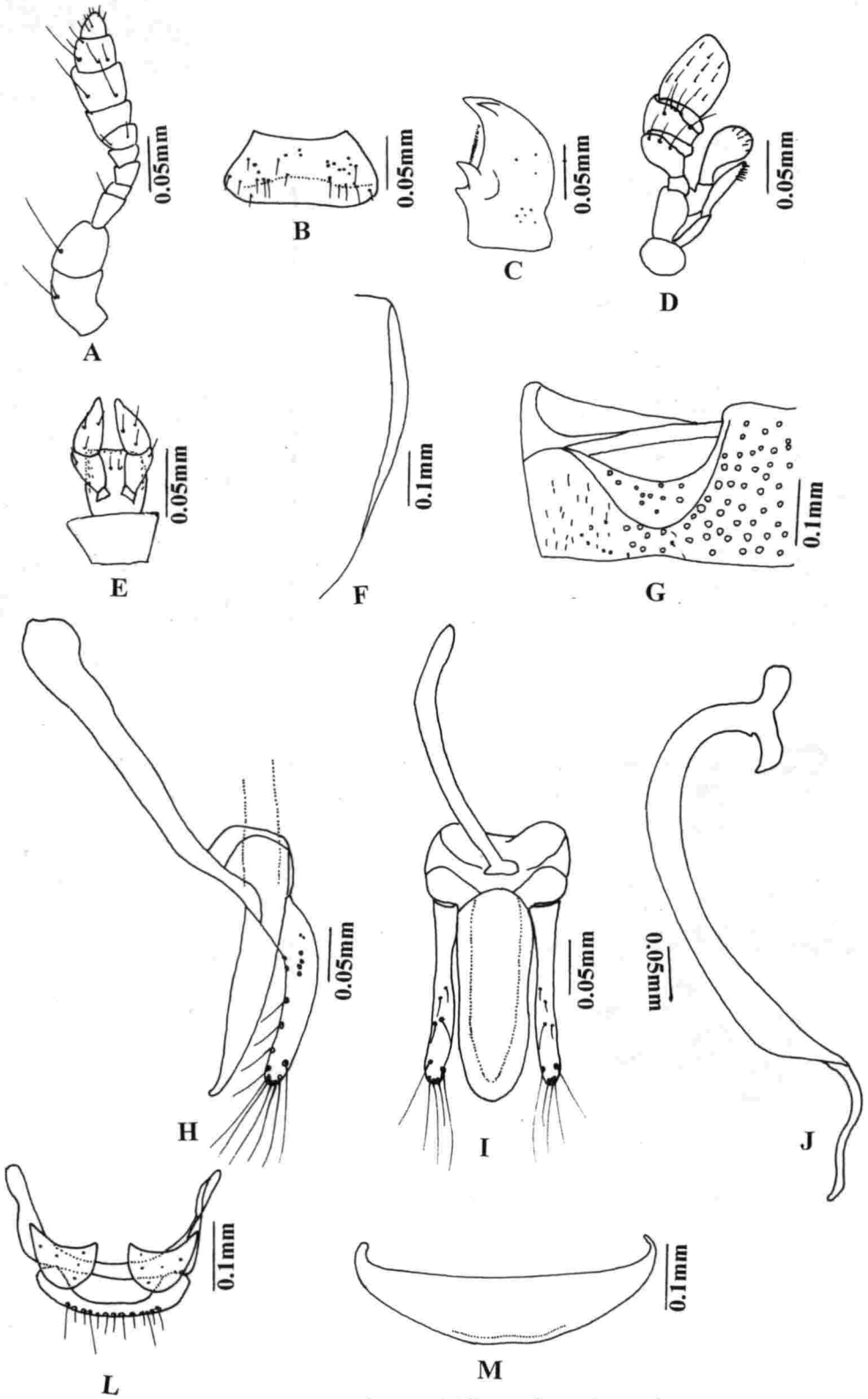


Fig. 37. *Stethorus* (*Allostethorus*) sp. 1

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. elytral epipleuron; G. abdominal postcoxal line; H. tegmen, lateral; I. tegmen, ventral; J. penis; L. genital segment of male; M. sixth abdominal ventrite of male

Measurements: Total length: 1.19 (1.16 - 1.25) mm, total width: 0.87 (0.81 - 0.92) mm, TL/TW: 1.37(1.31 - 1.43), PL/PW: 0.49 (0.47 - 0.53), EL/EW: 1.07 (1.03 - 1.11), EW/PW: 1.29 (1.20 - 1.35).

Material: India: Kerala: 4unsexed, Padannakkad, 20.xii.2015 (VCV); 3unsexed, Marakkal, 20.ii.2016 (VCV); 4unsexed, Ambalavayal, 25.ii.2016 (VCV); **Tamil Nadu:** 6unsexed, Tiruchirappalli, 24.i.2016 (VCV).

Prey/Associated host: *Tetranychus* sp. on coconut.

Remarks: Resemblance of this species with *Stethorus* (*Allostethorus*) *pauperculus* is discussed in 4. 1. 2. 1. 2. 2. 2.

Subgenus *Stethorus* (*Stethorus*) Weise, 1885

Scymnus (Stethorus) Weise, 1885: 65.

Body short oval, moderately convex, densely pubescent; body black with antennae, mouth parts yellowish or yellowish brown; legs completely or partly yellowish; antenna with 11 antennomeres; terminal maxillary palpomere slightly convergent; prosternal carina absent; tarsi trimerous; post coxal line of first abdominal ventrite complete; male genitalia with slender penis and parameres distinctly shorter than penis guide.

Remarks: Subgenus *Stethorus* is differentiated from *Allostethorus* by the presence of slender penis and tegmen with parameres distinctly shorter than penis guide.

4. 1. 2. 1. 2. 2. 5 *Stethorus* (*Stethorus*) *rani* Kapur, 1948 (Plate 10b & Fig. 38)

Stethorus rani Kapur, 1948: 313.

Diagnosis: This species is identified by the following characters: penis irregularly curved, penis guide tapering towards apex and slightly bent towards the parameres and last visible abdominal ventrite of male more or less truncate at the apical margin.

Description: Body small, relatively round, strongly convex, dorsum with greyish pubescence; head, pronotum, elytra and ventral side black, antennae, mouth parts, parts of femora, tibiae and tarsi reddish yellow; antenna with 11 antennomeres, width increases gradually from 6th antennomeres onwards; terminal maxillary

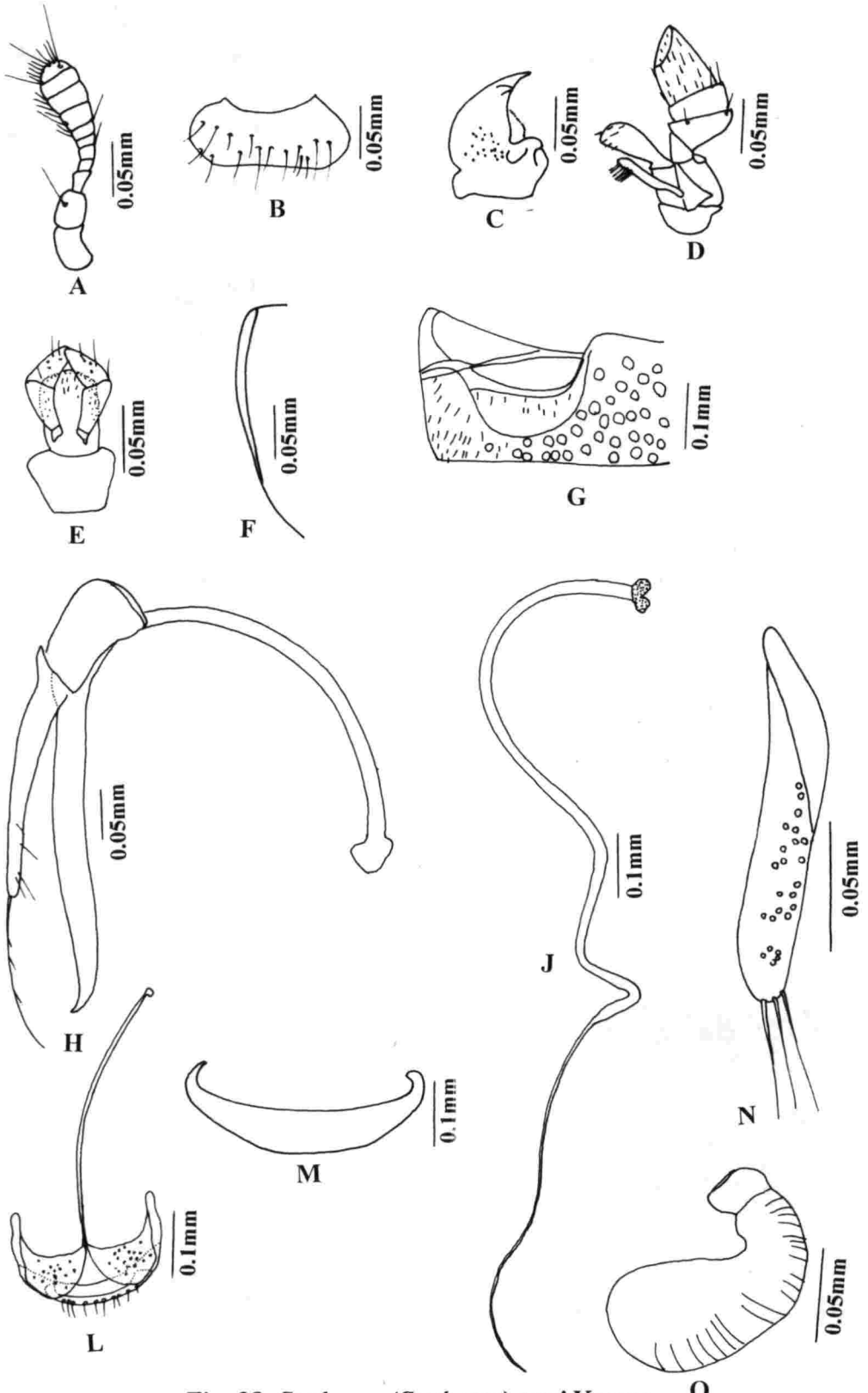


Fig. 38. *Stethorus* (*Stethorus*) *rani* Kapur

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. elytral epipleuron; G. abdominal postcoxal line; H. tegmen, lateral; J. penis; L. genital segment of male; M. sixth abdominal ventrite of male; N. hemisternite; O. spermatheca

palpomere slightly convergent; post coxal line of first abdominal ventrite complete, semicircular, extending more than half the length of abdominal ventrite, area enclosed by the line with a few smooth punctures, sparsely arranged; sixth abdominal ventrite of males more or less truncate at the posterior margin.

Male genitalia: Tegmen with parameres extending more than half the length of penis guide, with polyfurcate hair process that extends beyond the length of penis guide, short setae of hairs arranged near inner margin; penis guide tapering towards the apex which is slightly bent towards the parameres; trabes elongated and dark; penis long, narrow, tubular, irregular shaped, thread like towards apex, penis capsule like a dark knob with irregular outline; ninth abdominal segment with well sclerotized, long, slender apophysis without any dilation distally.

Female genitalia: Hemisternite boat shaped, apical region broad with a few short setae; spermatheca slightly curved.

Measurements: Total length: 1.21 (1.10 - 1.26) mm, total width: 0.89 (0.81 - 0.94) mm, TL/TW: 1.35 (1.32 - 1.37), PL/PW: 0.47 (0.44 - 0.52), EL/EW: 1.06 (1.03 - 1.08) EW/PW: 1.34 (1.30 - 1.38).

Material: India: Kerala: 12 unsexed, Pampadumpara, 30.iii.2016 (VCV).

Prey/Associated host: *Tetranychus* sp. on cardamom.

Remarks: *Stethorus* (*Stethorus*) *rani* and *S.* (*S.*) sp. 1 are closely related species with polyfurcate process at the apex of parameres. But the penis is irregular shaped in *S.* (*S.*) *rani*, whereas loop shaped in *S.* (*S.*) sp. 1. Penis guide tapering towards the apex and apex is slightly bent towards the parameres in *S.* (*S.*) *rani*. The sixth abdominal ventrite of *S.* (*S.*) *rani* is truncate whereas it is weakly emarginate in *S.* (*S.*) sp. 1.

4. 1. 2. 1. 2. 2. 6. *Stethorus* (*Stethorus*) sp. 1 (Plate 10c & Fig 39)

Diagnosis: This species is characterised by the presence of penis which is looped at the basal 2/3rd of its length and last visible abdominal ventrite of male emarginate at the apical margin.

Description: Body small, oblong oval, fairly convex, dorsum with dense silvery white pubescence; head, pronotum, elytra and ventral side black, antenna and

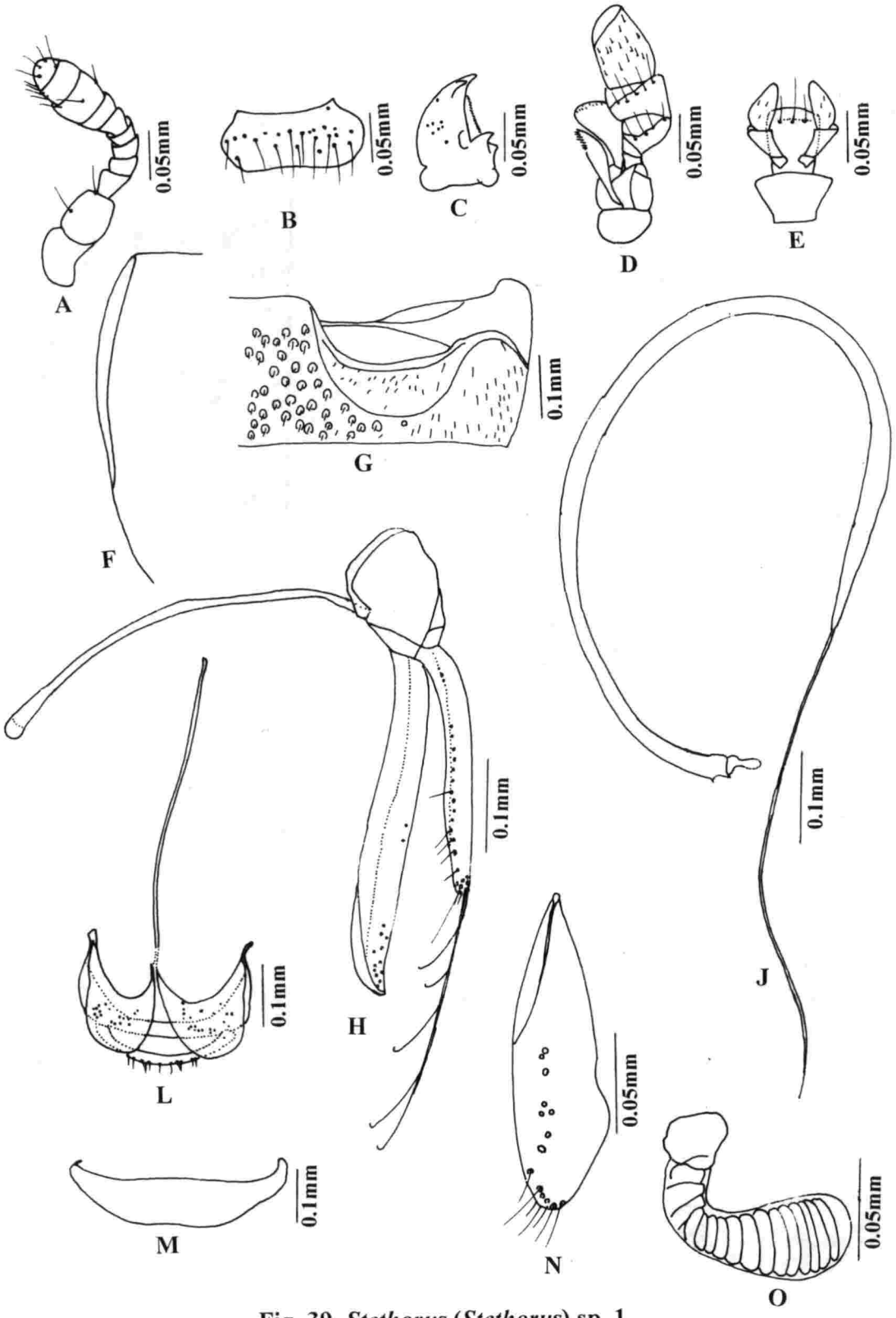


Fig. 39. *Stethorus* (*Stethorus*) sp. 1

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. elytral epipleuron; G. abdominal postcoxal line; H. tegmen, lateral; J. penis; L. genital segment of male; M. sixth abdominal ventrite of male; N. hemisternite; O. spermatheca

mouth parts yellowish, legs yellow except black coxae; antenna with 11 antennomeres, terminal four antennomeres forming the club; terminal maxillary palpomere slightly convergent; post coxal line of first abdominal ventrite complete, semicircular, extending more than half the ventrite, area enclosed by the line with a few smooth and sparse punctures; sixth abdominal ventrite of males weakly emarginate at the posterior margin.

Male genitalia: Tegmen with parameres extending more than half the length of penis guide, with polyfurcate hair process that extends much beyond the length of penis guide, short setae of hairs arranged near inner margin; penis guide long, both margins run parallel upto preapical region, thereafter join to form apex which is not pointed; trabes elongated; penis long, narrow, tubular, basal 2/3rd region loop shaped, tapering towards apex, penis capsule like a small knob; ninth abdominal segment with well sclerotized, long, slender apophysis without any dilation distally.

Female genitalia: Hemisternite subtriangular, pointed at the proximal part, broad at apex with short hairs; spermatheca curved 2/3rd from distal end.

Measurements: Total length: 1.31 (1.27 - 1.37) mm, total width: 0.96 (0.93 - 1.00) mm, TL/TW: 1.36 (1.35 - 1.37), PL/PW: 0.48 (0.47 - 0.48), EL/EW: 1.07 (1.06 - 1.08), EW/PW: 1.33 (1.30 - 1.35).

Material: India: Kerala: 7unsexed, Ambalavayal, 25.ii.2016 (VCV).

Prey/Associated host: *Brevipalpus phoenicis* (Geijskes) on pomegranate.

Remarks: The similarity of *Stethorus* (*Stethorus*) sp. 1 with *S.* (*S.*) *rani* is discussed in Chapter 4. 1. 2. 1. 2. 2. 5.

4. 1. 2. 1. 2. 2. 7. *Stethorus* (*Stethorus*) sp. 2 (Plate 10d & Fig.40)

Diagnosis: Tegmen bent towards the base and parameres slender with single long setae at the apex. Last abdominal ventrite of male distinctly emarginate at the apical margin.

Description: Body small, relatively round, strongly convex, dorsum with greyish pubescence; head, pronotum, elytra and ventral side black, antennae, mouth parts, parts of femora, tibia and tarsi reddish yellow; antenna with 11 antennomeres, width increases gradually from 6th antennomere onwards; terminal maxillary palpomere

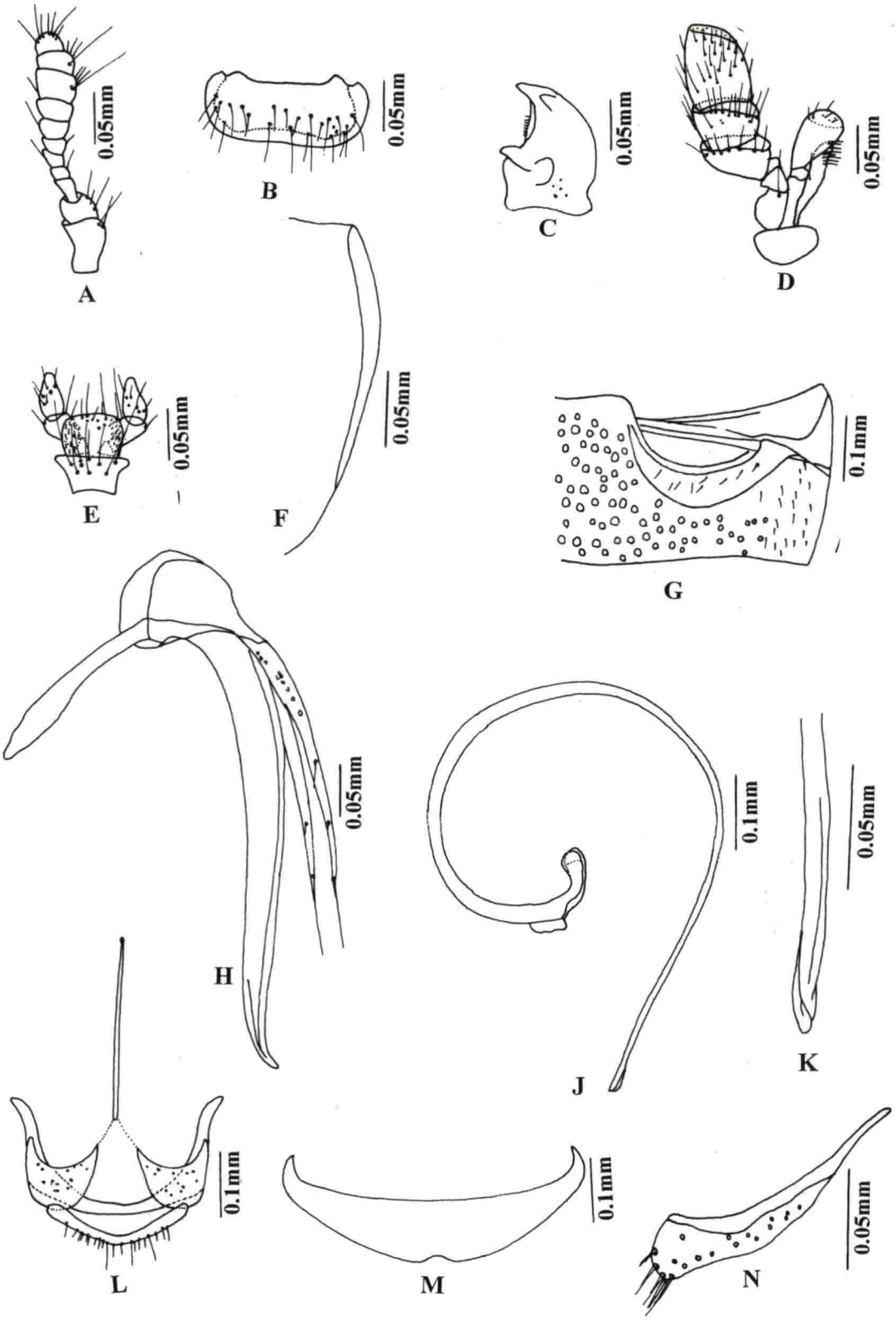


Fig. 40. *Stethorus* (*Stethorus*) sp. 2

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. elytral epipleuron; G. abdominal postcoxal line; H. tegmen, lateral; J. penis; K. penis apex; L. genital segment of male; M. sixth abdominal ventrite of male; N. hemisternite

slightly convergent; mouth parts with relatively more setae; post coxal line of first abdominal ventrite complete, widely rounded, extending half of abdominal ventrite, area enclosed by the line with a few smooth, sparsely arranged punctures; sixth abdominal ventrite of males distinctly emarginated at the posterior margin.

Male genitalia: Tegmen bent at the basal 1/4th portion; parameres slender with a distinct seta at the apex and one or two setae at the apical half; penis guide long, gradually narrowed towards apex, apex distinctly curved outwards, not pointed in lateral view, trabes moderately long with slightly dilated distal end, darker, curved along with phallobase, hence tegmen appears 'inverted U-shaped'; penis slender, tube like, basal 2/3rd length strongly curved, penis apex blunt; penis capsule darker, inner arm narrow and curved at the base, rounded distally, which is weakly chitinised and so light coloured; ninth abdominal segment with well sclerotized, long, slender apophysis without any dilation distally.

Female genitalia: Hemisternite boat shaped with narrow base and broad apex with a few numbers of short setae; spermatheca absent.

Measurements: Total length: 1.40 mm, total width: 1.06 mm, TL/TW: 1.32, PL/PW: 0.44, EL/EW: 1.01, EW/PW: 1.39.

Material: India: Tamil Nadu: 8 unsexed, Tiruchirappalli, 24.i.2016 (VCV).

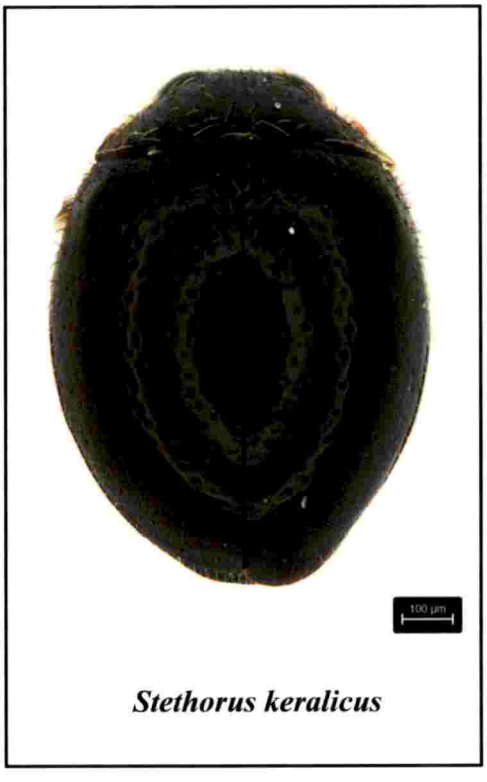
Prey/Associated host: *Tetranychus* sp. on *Desmodium* sp.

Remarks: *Stethorus* (*Stethorus*) sp. 2 and *Stethorus* (*S.*) sp. 3 shows similarity by the presence of tubular penis, but differ in the shape of parameres. The parameres with one or two stout setae at the apical half in *S.* (*S.*) sp. 2, whereas a few number of setae are present in *S.* (*S.*) sp. 3. The sixth abdominal ventrite is relatively deeply notched in *S.* (*S.*) sp. 2.

4. 1. 2. 1. 2. 2. 8. *Stethorus* (*Stethorus*) sp. 3 (Plate 11a; Fig.41)

Diagnostic characters: Body very small, oval, fairly convex, dorsum with silvery white pubescence; head, pronotum, elytra and ventral side black, antennae and mouth parts yellowish, legs yellow except black coxae; antenna with 11 antennomeres, width of terminal segments broadened gradually; post coxal line of first abdominal ventrite complete, shallowly semicircular, extending 3/4th length of

Stethorus (*Stethorus*) sp. 3



Stethorus keralicus

Plate 11. Species of Stethorini

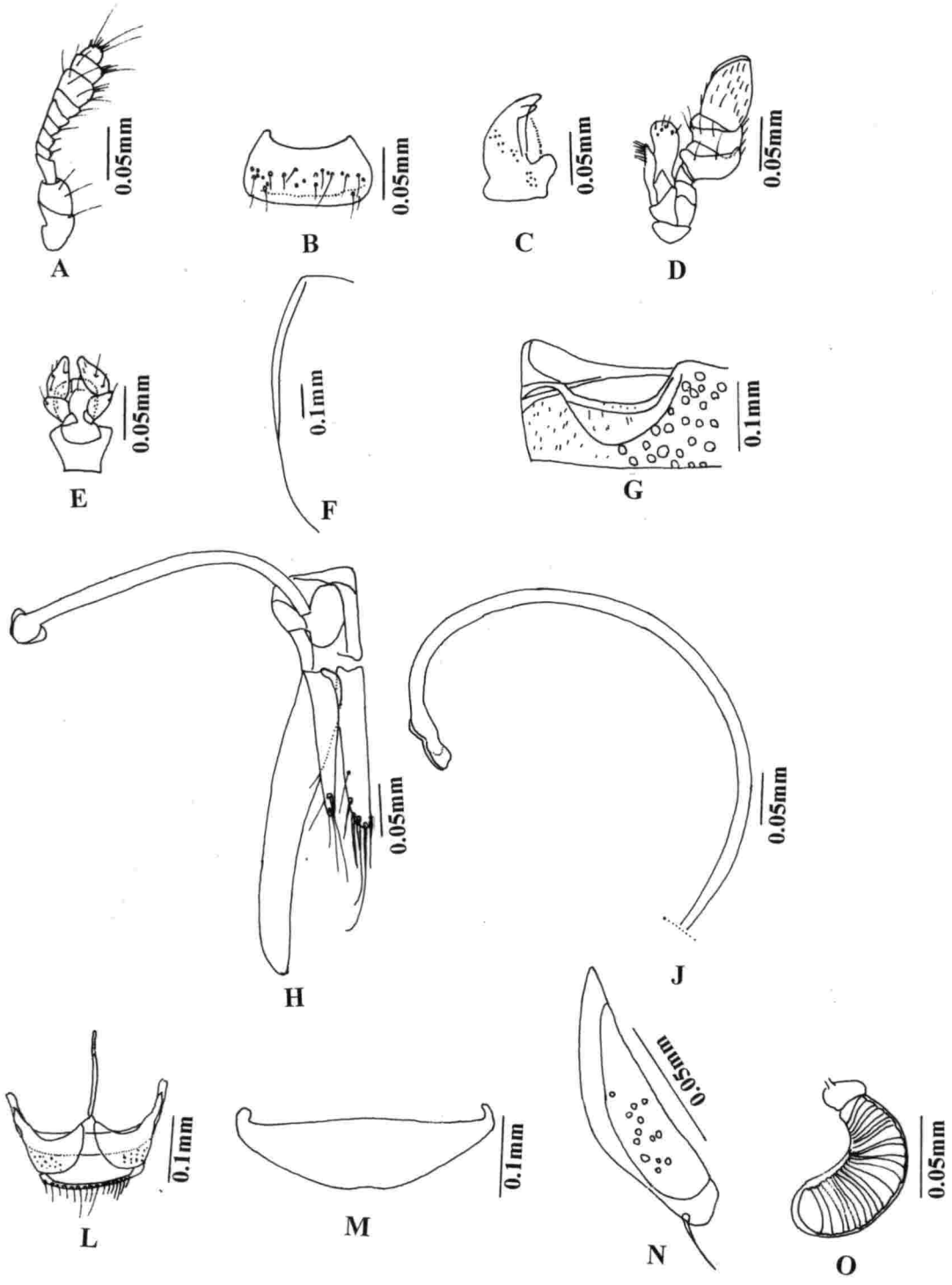


Fig. 41. *Stethorus* (*Stethorus*) sp. 3

A.antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. elytral epipleuron; G. abdominal postcoxal line; H. tegmen, lateral; J. penis; L. genital segment of male; M. sixth abdominal venrite of male; N. hemisternite; O. spermatheca

abdominal ventrite, area enclosed by the line with a few smooth punctures; sixth abdominal ventrite of males weakly emarginate at the posterior margin.

Male genitalia: Tegmen with parameres half the length of penis guide in the lateral view, parameres with a few numbers of setae at the apical half; penis guide narrowed towards apex in lateral view; trabes darker, slightly curved, knobbed at the distal end; penis tubular, with long inner arm, but without an outer arm; ninth abdominal segment with medium long, well sclerotized, slender apophysis without any dilation distally.

Female genitalia: Hemisternite with broad apical end and pointed proximal end; spermatheca C-shaped.

Measurements: Total length: 0.94 (0.91 - 0.98) mm, total width: 0.68 (0.67 - 0.71) mm, TL/TW: 1.37 (1.35 - 1.39), PL/PW: 0.47 (0.46 - 0.49), EL/EW: 1.10 (1.05 - 1.17), EW/PW: 1.33 (1.27 - 1.36).

Material: India: Kerala: 4unsexed, Vellayani, 20.iv.2016 (VCV).

Prey/Associated host: Arecanut (prey not known).

Remarks: Similarity of *Stethorus* (*Stethorus*) sp. 3 to *S.* (*S.*) sp. 2 is discussed in Chapter 4. 1. 2. 1. 2. 2. 7.

Species *incertae sedis*

One of the species *Stethorus*, *S. keralicus*, collected during the study, varied distinctly from the characters of already described genera of *Stethorus*. It has short penis and stout penis guide, which is in agreement with the character of subgenus *Allostethorus*, but the length of parameres distinctly shorter than penis guide, which is the character of subgenus *Stethorus*. Hence this species, *S. keralicus* is treated separately.

4. 1. 2. 1. 2. 2. 9. *Stethorus keralicus* Kapur, 1961 (Plate 11b & Fig.42)

Stethorus keralicus Kapur, 1961: 35.-Poorani, 2017: 596.

Stethorus curvus Hoang 1985: 27. -Synonymised by Poorani, 2017: 596.

Diagnosis: This species is identified by the following characters: antenna with 10 antennomeres, tegmen curved with stout phallobase and a small finger like process

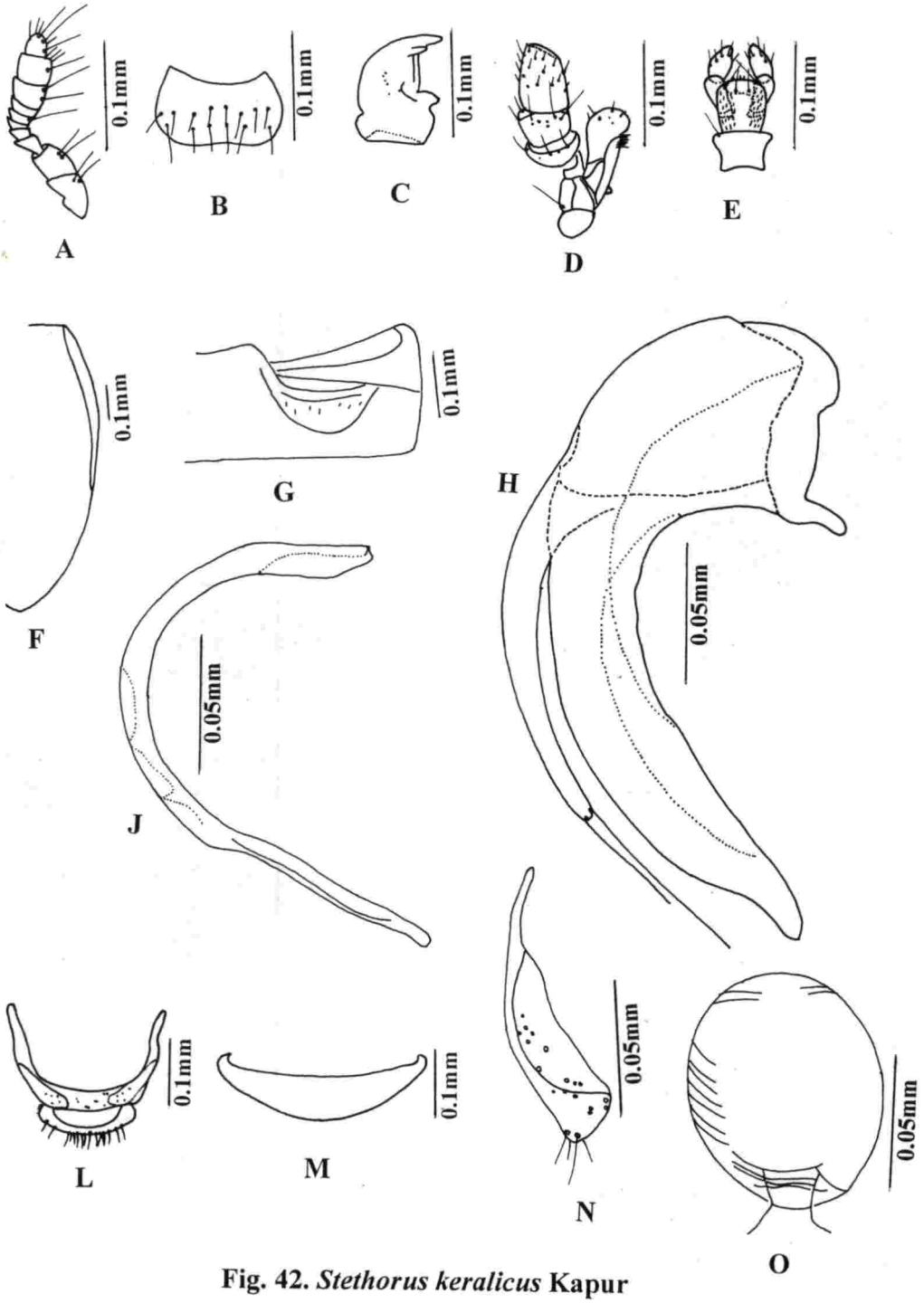


Fig. 42. *Stethorus keralicus* Kapur

A. antenna; B. labrum; C. mandible; D. maxilla; E. labium; F. elytral epipleuron; G. abdominal postcoxal line;; H. tegmen, lateral; J. penis; L. genital segment of male; M. sixth abdominal ventrite of male; N. hemisternite; O. spermatheca

towards inner margin, trabes absent, penis stout, short, completely inserted inside the penis guide, and penis capsule lacking.

Description: Body very small, shortly oval, strongly convex, dorsum with greyish pubescence. Head, pronotum, elytra and ventral side black, antennae and mouth parts reddish yellow, legs black except 1/4th femur, tibiae and tarsi reddish yellow; antenna with 10 antennomeres, 8th and 9th antennomeres broader; terminal maxillary palpomere slightly convergent; post coxal line of first abdominal ventrite complete, semicircular, extending 2/3rd of abdominal ventrite, area enclosed by the line with a few smooth punctures mainly confined towards anterior area; sixth abdominal ventrite rounded in both males and females.

Male genitalia: Tegmen curved with stout phallobase with a small finger like process towards inner margin; parameres narrow with two long setae at the apex, longer than half the length of penis guide; penis guide wider, of uniform width about 5/6th of its length and then narrowed to a blunt apex, inner margin of penis guide upto 1/5th length weakly wavy for a short distance in lateral view, trabes absent; penis stout, short, completely inserted inside the penis guide, penis semicircularly curved, narrowed towards apical 1/3rd length with a blunt apex; penis capsule lacking.

Female genitalia: Hemisternite subtriangular, narrow base and broad apex with a few numbers of short setae; spermatheca globular with a short base.

Material: Kerala: 25unsexed, Vandazhy, 30.vii.2015, 30.vii.2016 (VCV); 14unsexed, Vellanikkara, 07.vi.2015 (VCV); 8unsexed, Vadakkenchery, 09.xii.2015 (VCV); 5unsexed, Padannakkad, 20.xii.2015 (VCV); 11unsexed, Ambalavayal, 25.ii.2016 (VCV); 16unsexed, Mukkam, 05.iii.2016 (VCV); 18unsexed, Kayamkulam, 09.iii.2016 (VCV); 12unsexed, Vellayni, 19.iv.2016 (VCV); 7unsexed, Sreekaryam, 21.iv.2016 (VCV); **Karnataka:**24unsexed, Shivamogga, 04.iv.2016 (VCV); 1unsexed, Dharwad, 16.ix.2016 (VCV); **Tamil Nadu:** 3unsexed, Tiruchirappalli, 24.i.2016 (VCV). 5unsexed, Madurai, 11.xii.2015 (VCV).

Prey/Associated host: *Raoiella indica* (Hirst) on arecanut, banana, coconut.

4. 1. 3. Prey range and distribution

4. 1. 3. 1. Prey range and distribution of species of Scymnini

The prey range and distribution records of the species of Scymnini studied are documented below (Table 7; Fig. 43a-g). The prey for Scymnini included different families of Hemiptera belonging to the suborder Sternorrhyncha *viz.*, Aphididae (aphids), Pseudococcidae (mealybugs), Aleyrodidae (whiteflies) and Coccidae (scales). Thirteen species of mealybugs *viz.*, *Coccidohystrix insolita* (Green), *Ferrisia virgata* (Cockerell), *Dysmicoccus brevipes* (Cockerell), *D. neobrevipes* (Beardsley), *Formicococcus polysperes* Williams, *Nipaecoccus viridis* (Newstead), *Paracoccus marginatus* Williams and Granara de Willink, *Phenacoccus madeirensis* Green, *P. solenopsis* Tinsley, *Planococcus citri* (Risso), *Pseudococcus jackbeardsleyi* Gimpel and Miller, *Pseudococcus longispinus* (Targioni and Tozzetti) and *Saccharicoccus sacchari* (Cockerell); five species of aphids *viz.*, *Aphis craccivora* Koch, *A. gossypii* Glover, *Pentalonia nigronervosa* Coquerel, *Rhopalosiphum maidis* (Fitch) and *Toxoptera odinae* (van der Goot); two speceis of whiteflies *viz.*, *Aleurodicus dispersus* Russell and *Bemisia tabaci* (Gennadius) and one speceis of scale were recorded as prey of different species of Scymnini.

Table 7. Prey and geographical distribution of Scymnini recorded during the study

Species	Prey range	Distribution
Axinoscymnus puttarudriahi H. Kamiya	*Aleurodicus dispersus* *Bemisia tabaci*	**Kerala:** Avinissery, Chalakkudy, Chazhur, Kumarakom, Marakkal, Moorkkanikkara, Padannakkad, Panniyur, Tavanur, Vadakarapathy, Vandazhy, Vellanikkara; Vellayani; **Karnataka:** Bengaluru, Dharwad; **Tamil**

		Nadu: Madurai, Tiruchirappalli
Axinoscymnus sp.1	Prey not known	**Kerala:** Kayamkulam
Cryptolaemus montrouzieri Mulsant	*Ferrisia virgata* *Paracoccus marginatus*, *Planococcus* sp.	**Kerala:** Ollur; **Karnataka:** Bengaluru; **Tamil Nadu:** Madurai, Tiruchirappilli.
Horniolus sororius Poorani	*Formicococcus polysperes*	**Kerala:** Pulpally
Nephus regularis (Sicard)	*Coccidohystrix insolita*, *Ferrisia virgata*, *Phenacoccus madeirensis*	**Kerala:** Padannakkad; **Karnataka:** Dharwad, Raichur; **Tamil Nadu:** Periyakulam, Tiruchirappalli, T. Kallupetti
Nephus tagiapatus (Kamiya)	*Saccharicoccus sacchari*	**Tamil Nadu:** Coimbatore
Nephus sp. 1	*Planococcus citri*	**Kerala:** Chazhur, Vadakkenchery, Vellanikkara; **Karnataka:** Shivamogga; **Tamil Nadu:** Madurai
Sasajiscymnus sp.1	Banana scale	**Kerala:** Avinissery
Scymnus (*Neopullus*) *hoffmanni* Weise	Aphids	**Kerala:** Vellanikkara
Scymnus (*Neopullus*) sp.1	Prey not known	**Kerala:** Kumarakom

Scymnus (*Pullus*) *castaneus* Sicard	*Aphis gossypii*	**Karnataka:** Dharwad; **Tamil Nadu:** Madathukulam
Scymnus (*Pullus*) *coccivora* Ayyar	*Coccidohystrix insolita*, *Ferrisia virgata*, *Paracoccus marginatus*, *Phenacoccus solenopsis*, *Planococcus citri*, *Pseudococcus longispinus*	**Kerala:** Kayamkulam, Kumarakom, Mannuthy, Padannakkad, Perumbavoor, Tavanur, Vadakarapathy, Vellanikkara; **Karnataka:** Bengaluru, Dharwad, Raichur, Shivamogga; **Tamil Nadu:** Coimbatore, Madurai, Periyakulam, Tiruchirappalli, Madathukulam
Scymnus (Pullus) latemaculatus Motschulsky	*Aphis craccivora*, *A. gossypii*, *Pentalonia nigronervosa*	**Kerala:** Kayamkulam, Marakkal, Parakkad, Pattikkad, Vadakarapathy, Vellanikkara, Vellayani; **Karnataka:** Raichur, Shivamogga; **Tamil Nadu:** Madathikulam, Madurai, Tiruchirappalli
Scymnus (Pullus) pyrocheilus Mulsant	*Aphis craccivora*, *A. gossypii*, *Toxoptera odinae*	**Kerala:** Avinissery, Cherpu, Kayamkulam, Kodannur, Vadakkenchery, Vandazhy, Vellanikkara, Vellayani; **Tamil Nadu:** Madathukulam Madurai, Periyakulam, Tiruchirapalli
Scymnus (*Pullus*) *utilis* Hoang	Mealybugs	**Kerala:** Avinissery, Kottepadam, Tiruchirappalli

Scymnus (Pullus) sp. 1	*Aphis craccivora*, *A. gossypii*	**Kerala:** Vandazhy, Vellanikkara; **Karnataka:** Dharwad, Shivamogga; **Tamil Nadu:** T. Kallupetti, Madurai
Scymnus (*Pullus*) sp. 2	*Aphis gossypii*	**Karnataka:** Dharwad
Scymnus (*Pullus*) sp. 3	*Aphis craccivora*	**Kerala:** Panniyur
Scymnus (*Pullus*) sp. 4	*Rhopalosiphum maidis*	**Kerala:** Ambalavayal, Kayamkulam, Marakkal, Parakkad, Vellanikkara, **Karnataka:** Bengaluru
Scymnus (*Pullus*) sp. 5	*Pentalonia nigronervosa*	**Kerala:** Avinissery, Panniyur; **Tamil Nadu:** Madurai
Scymnus (*Pullus*) sp. 6	*Coccidohystrix insolita*, *Ferrisia virgata*, *Nipaecoccus viridis*, *Phenacoccus solenopsis*, *Pseudococcus jackbeardsleyi*	**Kerala:** Avinissery, Chalakkudy, Panniyur, Pattikkad, Payyanam, Perumbavoor, Tavanur, Vadakkenchery, Vellanikkara
Scymnus (*Pullus*) sp. 7	*Dysmicoccus brevipes*, *D. neobrevipes*, *Phenacoccus solenopsis*, *Planococcus citri*, *Pseudococcus* sp.	**Kerala:** Ambalavayal, Avinissery, Banasura sagar, Elavally, Kumarakom, Mukkam, Vazhakulam, Vellanikkara
Scymnus (*Pullus*) sp.8	Mealybugs	**Kerala:** Kayamkulam

Scymnus (*Pullus*) sp. 9	*Dysmicoccus brevipes*, *D. neobrevipes*, *Phenacoccus solenopsis*, *Ferrisia virgata*	**Kerala:** Avinissery, Chalakkudy,Pampadumpara, Vazhakulam, Vellanikkara; **Tamil Nadu:** Madurai
Scymnus (*Pullus*) sp. 10	*Phenacoccus solenopsis*, *Pseudococcus longispinus*	**Karnataka:** Dharwad, Raichur; **Tamil Nadu:** T. Kallupetti
Scymnus (*Scymnus*) *nubilus* Mulsant	*Aphis craccivora*, *Rhopalosiphum maidis*	**Kerala:** Vellanikkara; **Karnataka:** Dharwad, Raichur; **Tamil Nadu:** Coimbatore
Scymnus saciformis	*Coccidohystrix insolita*, *Ferrisia virgata*, *Paracoccus marginatus*, *Phenacoccus solenopsis*, *Planococcus citri*, *Pseudococcus* sp.	**Kerala:** Ambalavayal, Avinissery, Banasura sagar, Chembukkavu, Elavally, Kayakulam, Kumarakom, Vadakkenchery, Vellanikkara; **Karnataka:** Bengaluru: **Tamil Nadu:** Coimbatore, Madurai, T. Kallupetti
Scymnus sp. 2	*Planococcus citri*	Ambalavayal

4. 1. 3. 2. Prey range and distribution of species of Stethorini

The prey range and distribution records of the species of Stethorini studied are documented below (Table 8; Fig. 44a-c). The prey for Stethorini belonged to seven species of two acarine families, Tetranychidae and Tenuipalpidae. Species of mites identified as prey for Stethorini include tetranychid mites *viz.*, *Eutetranychus orientalis* (Klein), *Oligonychus indicus* (Hirst), *Tetranychus macfarlanei* Baker and Pritchard, *T. okinawanus* Ehara, *Tetranychus truncatus* Ehara and tenuipalpid mites *viz.*, *Raoiella indica* (Hirst) and *Brevipalpus phoenicis* (Geijskes).

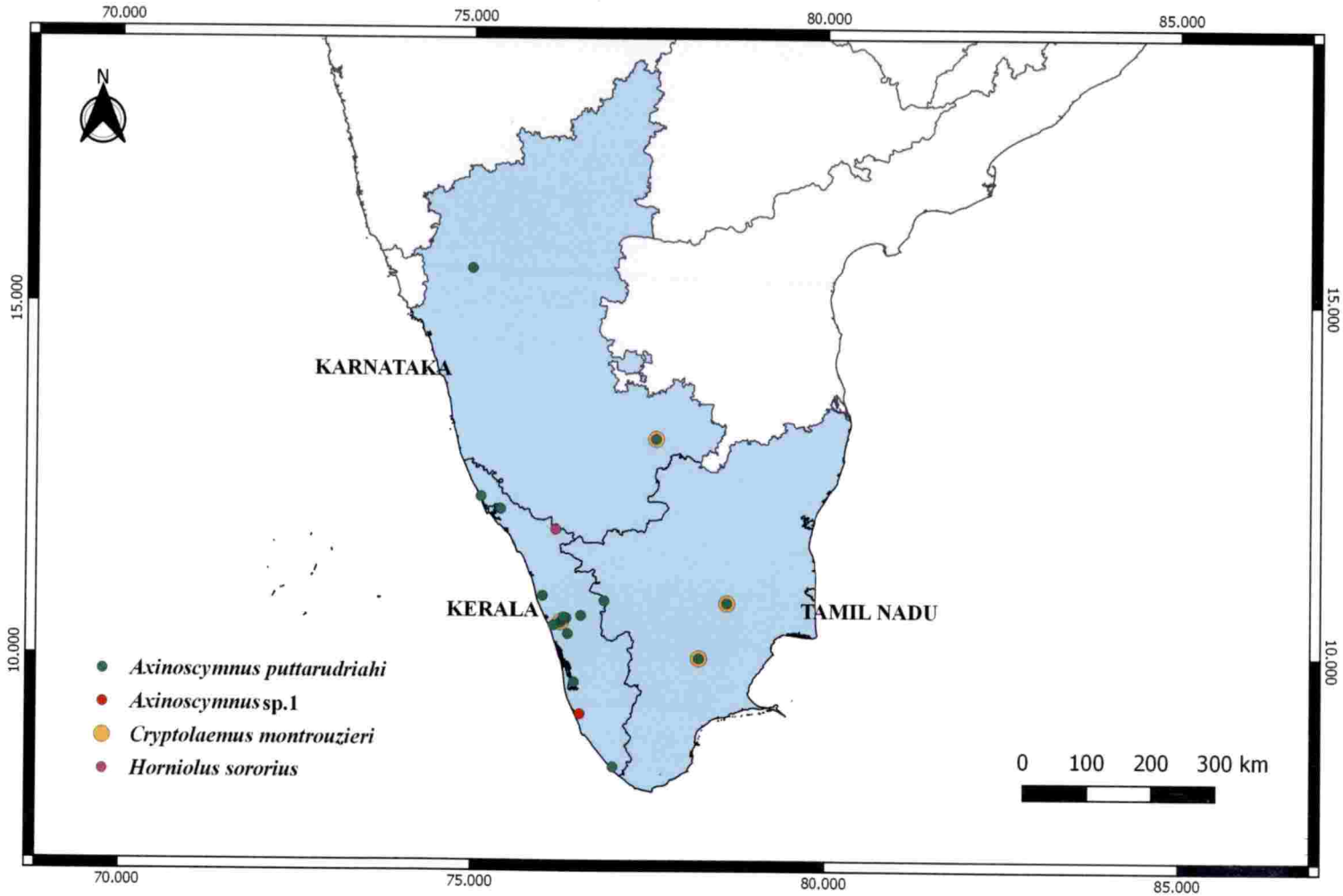


Fig. 43a. Distribution of species of Scymnini

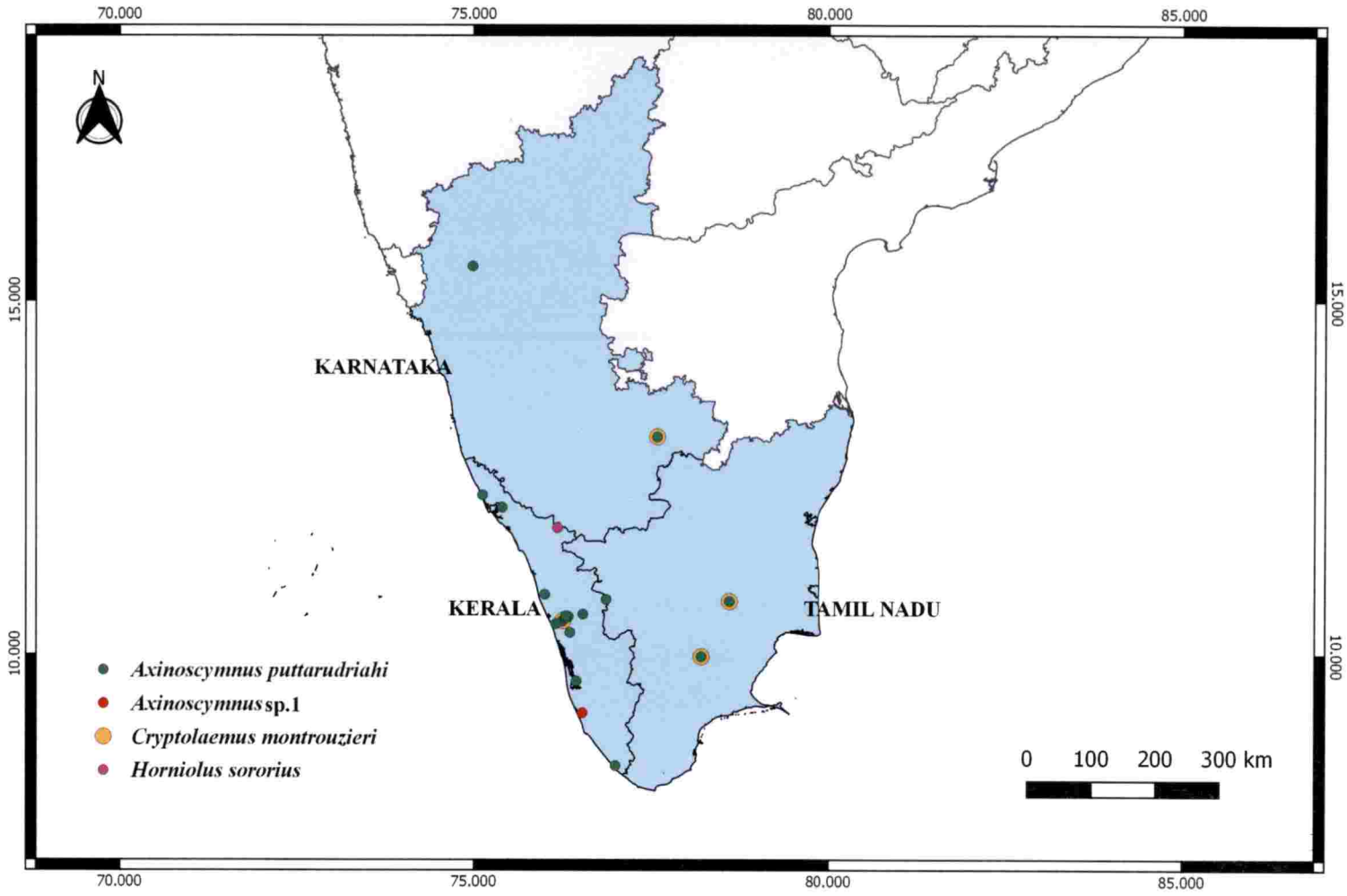


Fig. 43a. Distribution of species of Scymnini

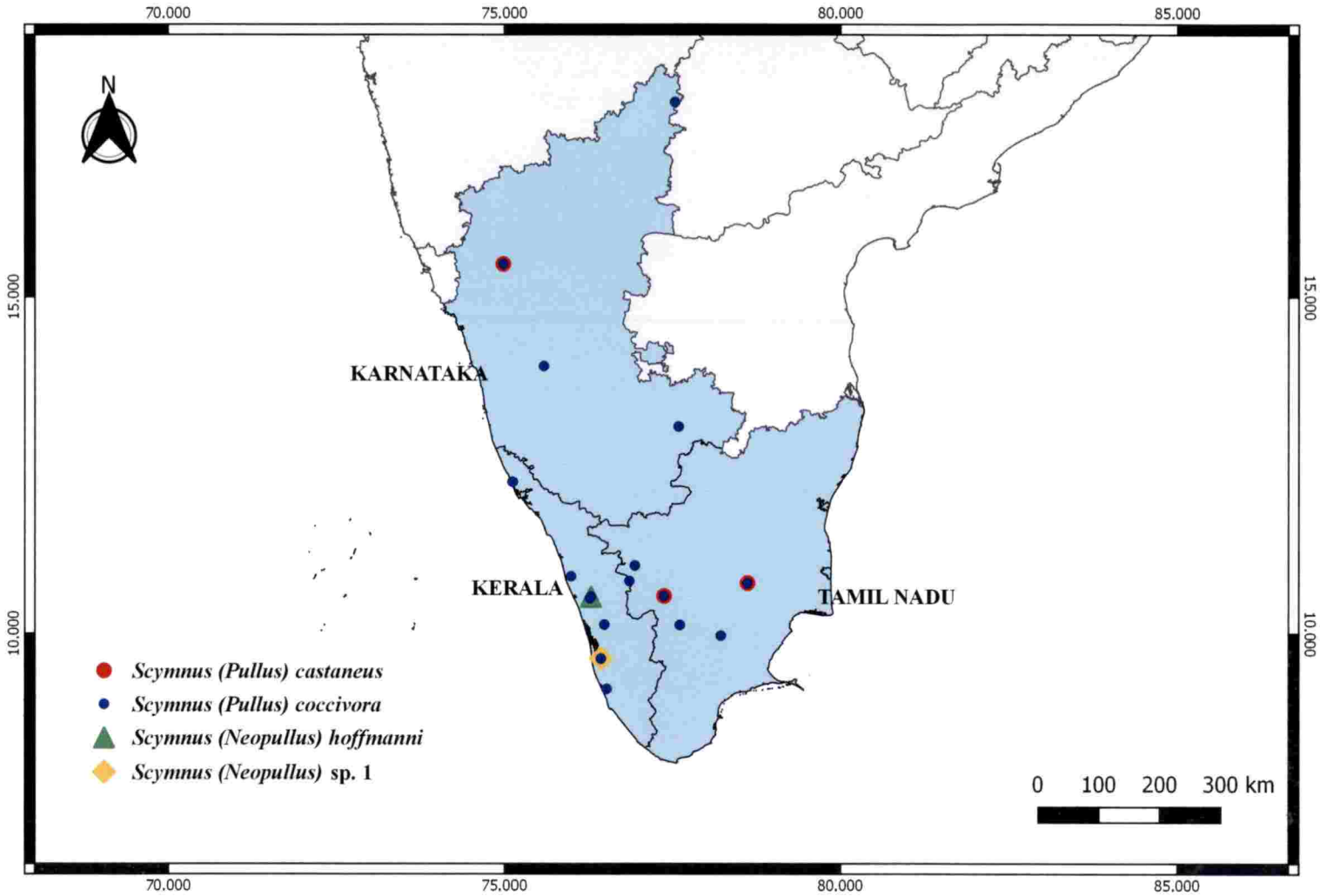


Fig. 43c. Distribution of species of Scymnini

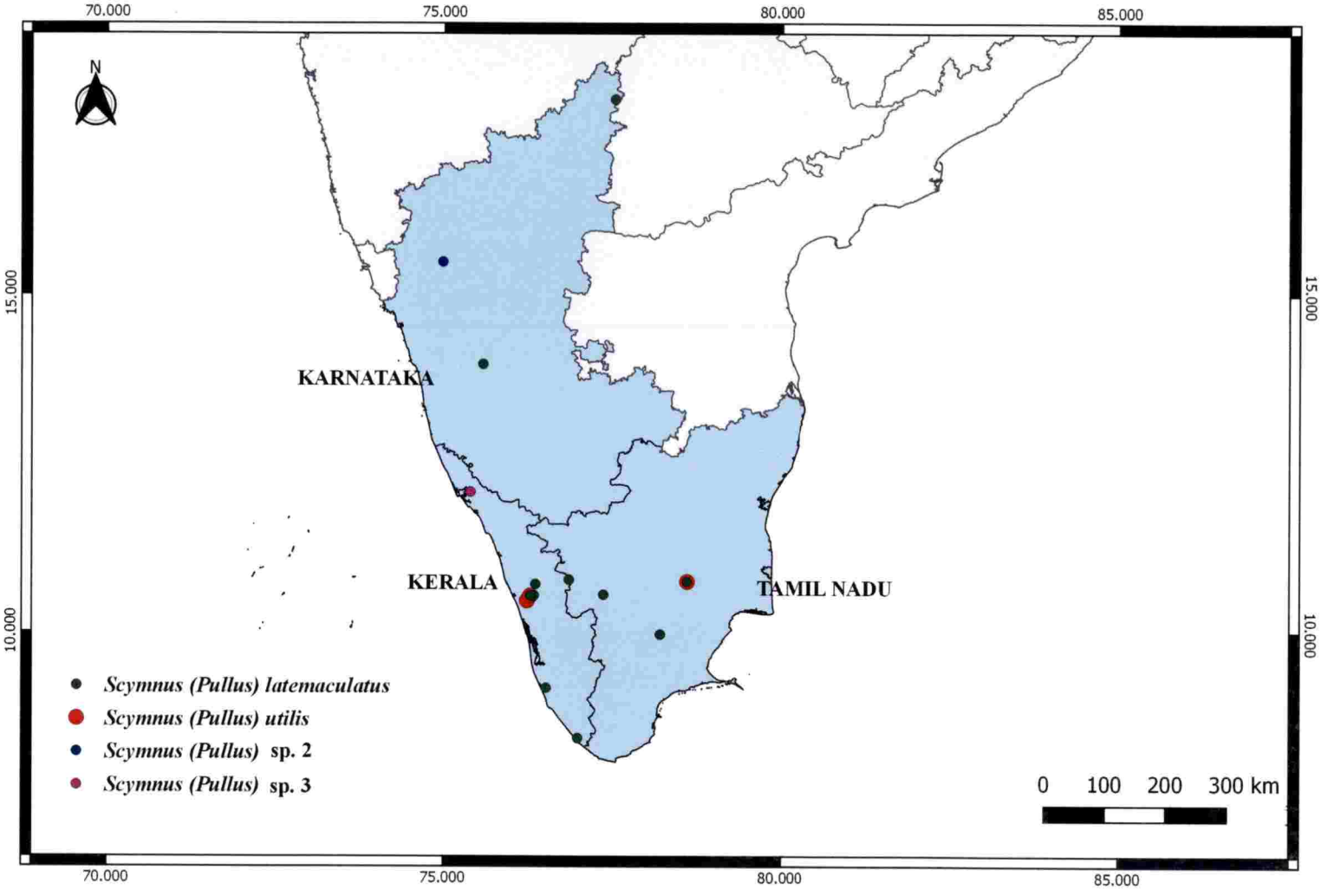


Fig. 43d. Distribution of species of Scymnini

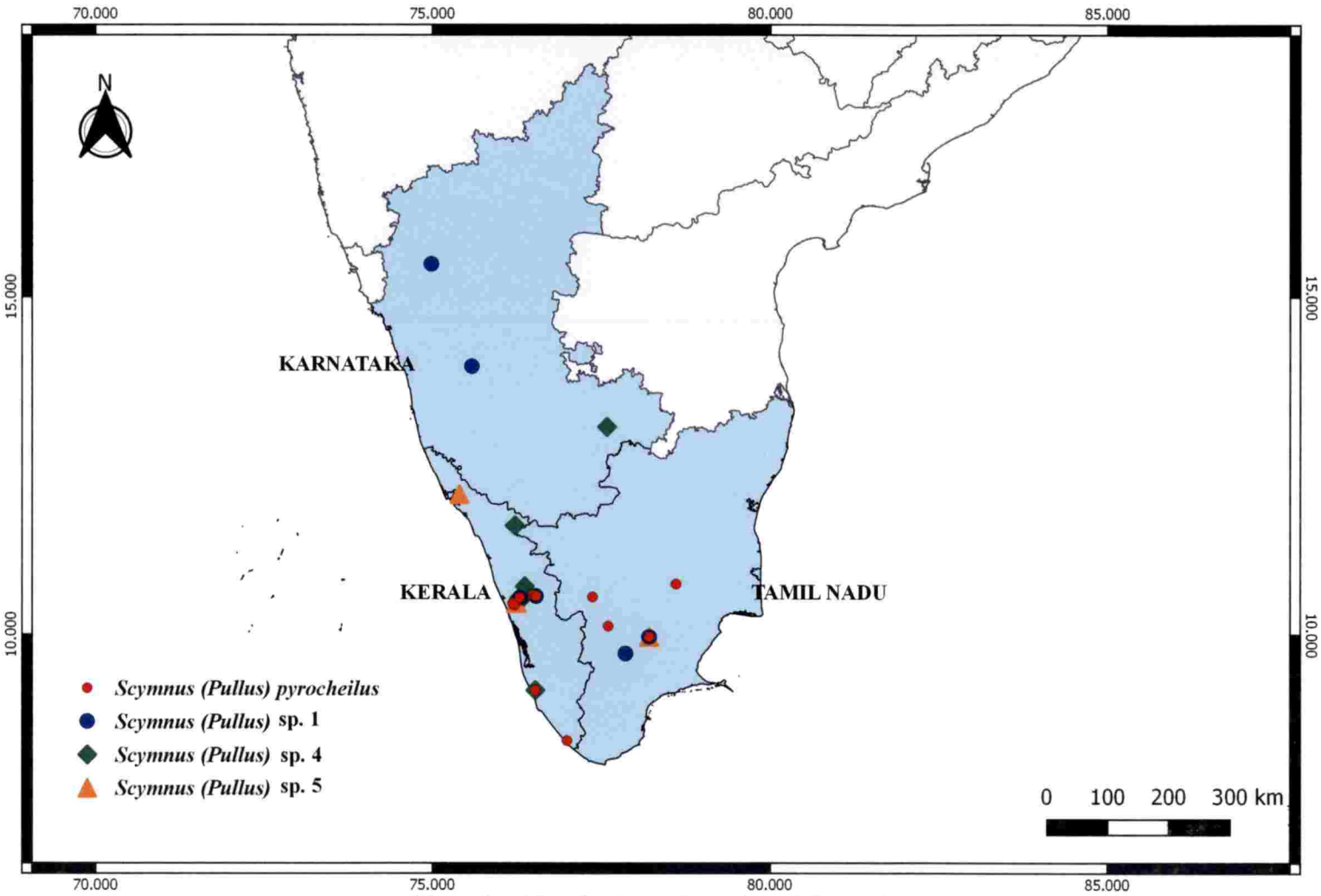


Fig. 43e. Distribution of species of Scymnini

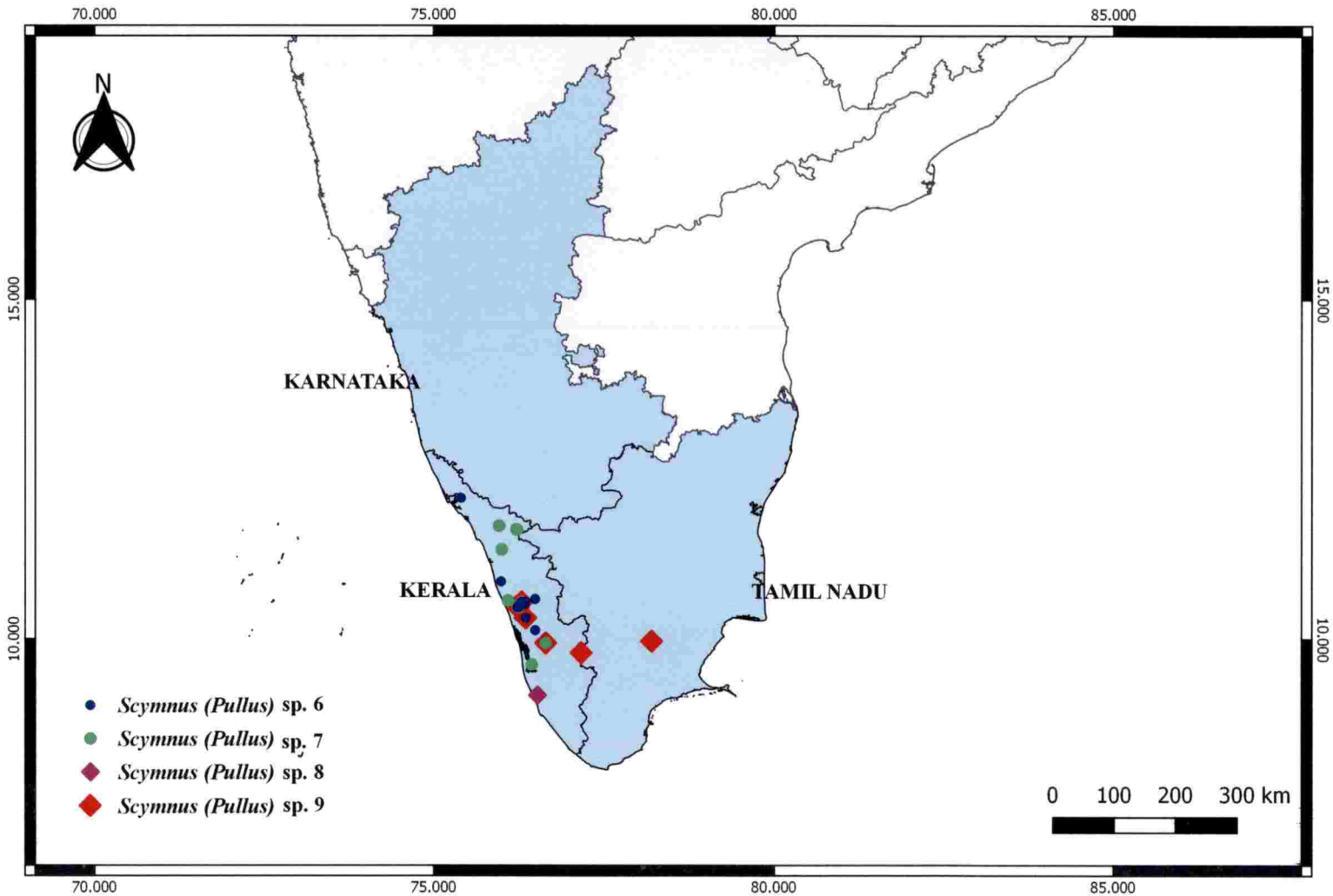


Fig. 43f. Distribution of species of Scymnini

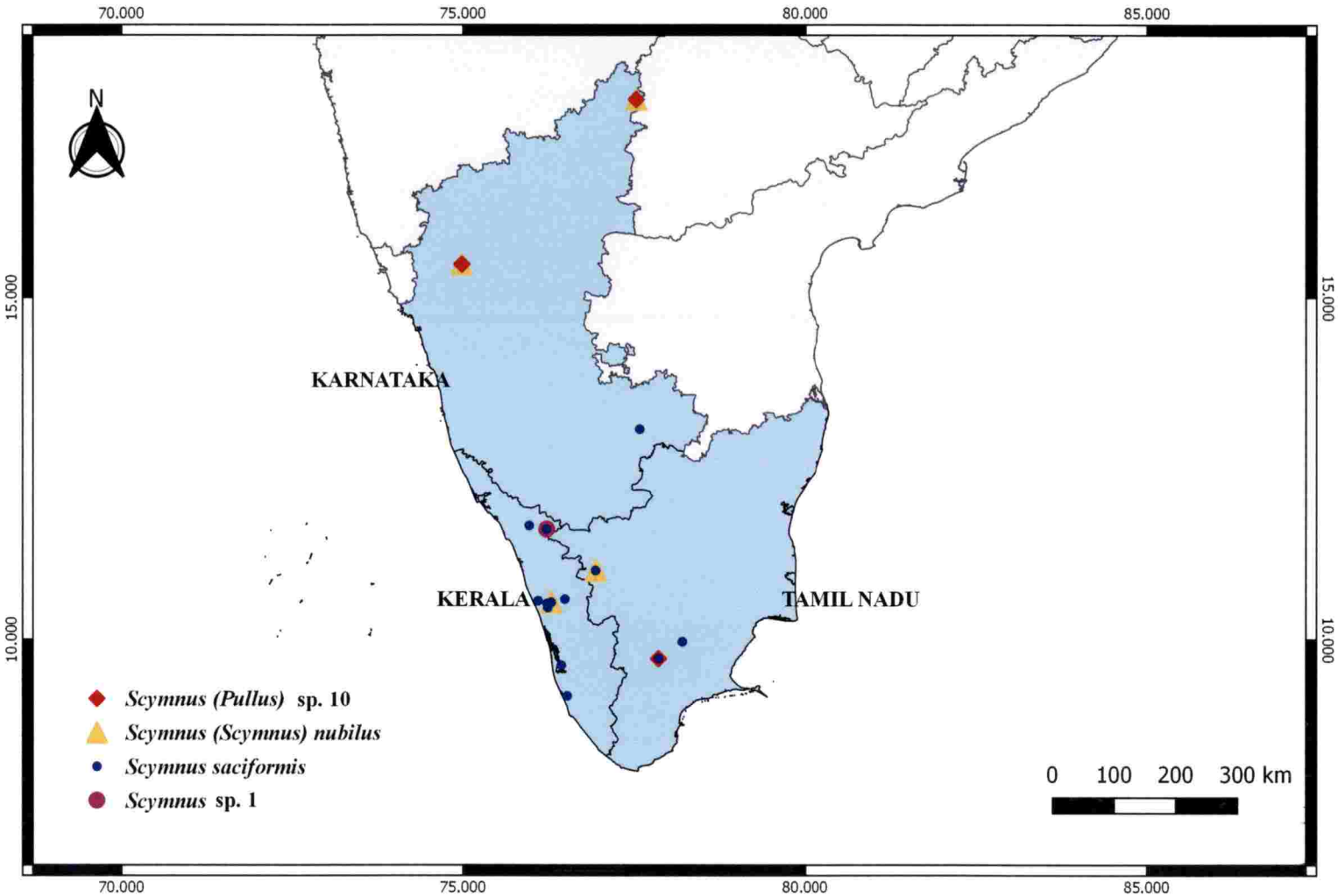


Fig. 43g. Distribution of species of Scymnini

Table 8. Prey and geographical distribution of Stethorini recorded during the study

Species	Prey range	Distribution
Parastethorus indira (Kapur)	*Eutetranychus orientalis*	**Kerala:** Ambalavayal, Marakkal, Olarikkara; **Tamil Nadu:** Madathukulam
Stethorus (*Allostethorus*) *forficatus* Poorani	*Tetranychus okinawanus, T. truncatus*	**Kerala:** Kayamkulam, Padannakkad, Payyanam, Tavanur, Vellanikkara, Vellayani; **Karnataka:** Bengaluru; **Tamil Nadu:** Coimbatore, Madurai
Stethorus (*Allostethorus*) *pauperculus* (Weise)	*Oligonychus indicus* , *Tetranychus macfarlanei*, *T. truncatus Tetranychus* sp.	**Kerala:** Ambalavayal, Avinissey, Chalakkudy, Kayamkulam, Kumarakom, Marakkal, Mukkam, Padannakkad, Sreekaryam, Vadakkenchery, Vellanikkara, Vellayani; **Karnataka:** Bengaluru, Hiriyur, Mandya, Raichur, Shivamogga; **Tamil Nadu:** Coimbatore, Madurai
Stethorus (*Allostethorus*) *tetranychi* Kapur	*Tetranychus* sp.	**Kerala:** Ambalavayal, Marakkal; **Karnataka:** Bengaluru; **Tamil Nadu:** Tiruchirappalli

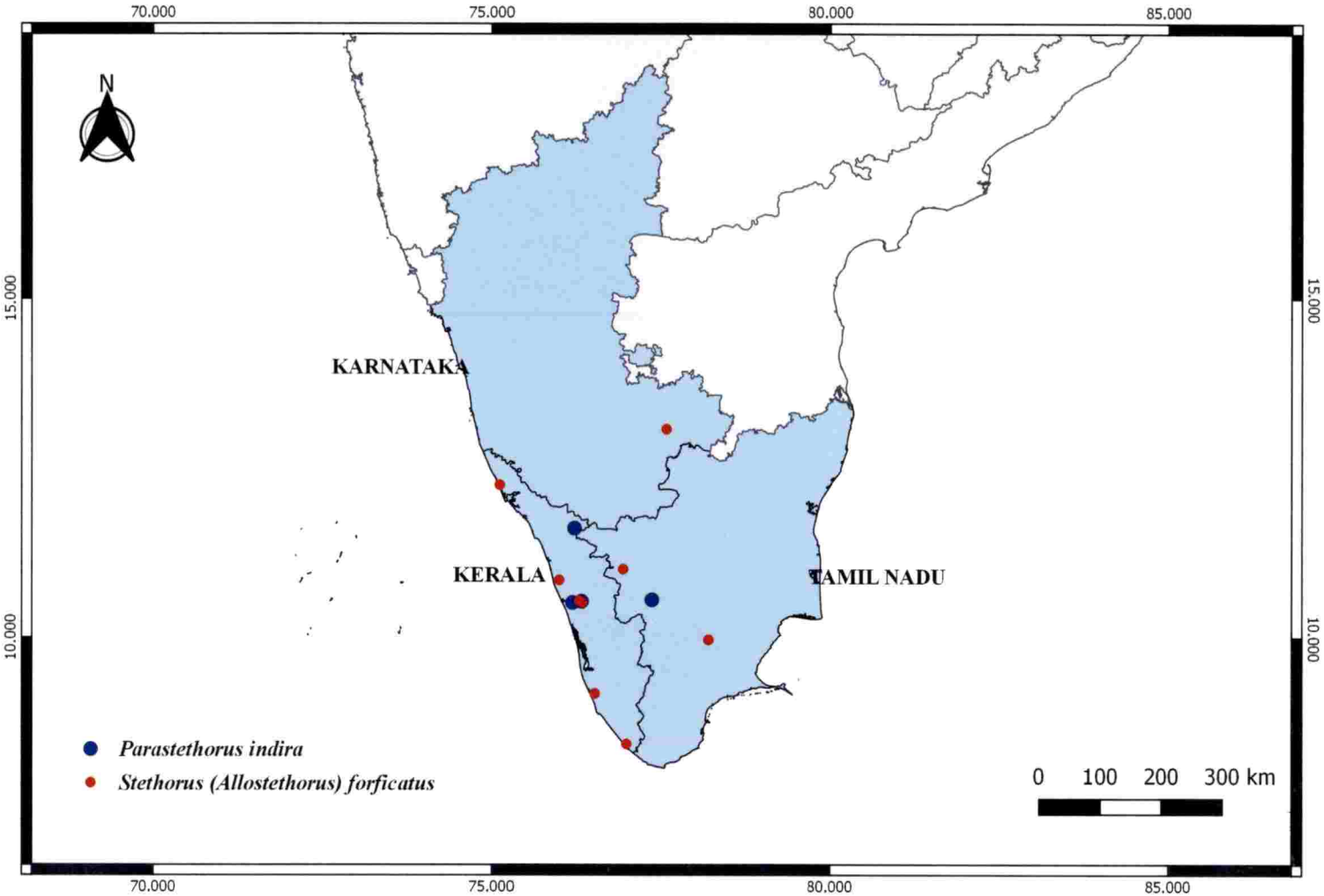


Fig. 44a. Distribution of species of Stethorini

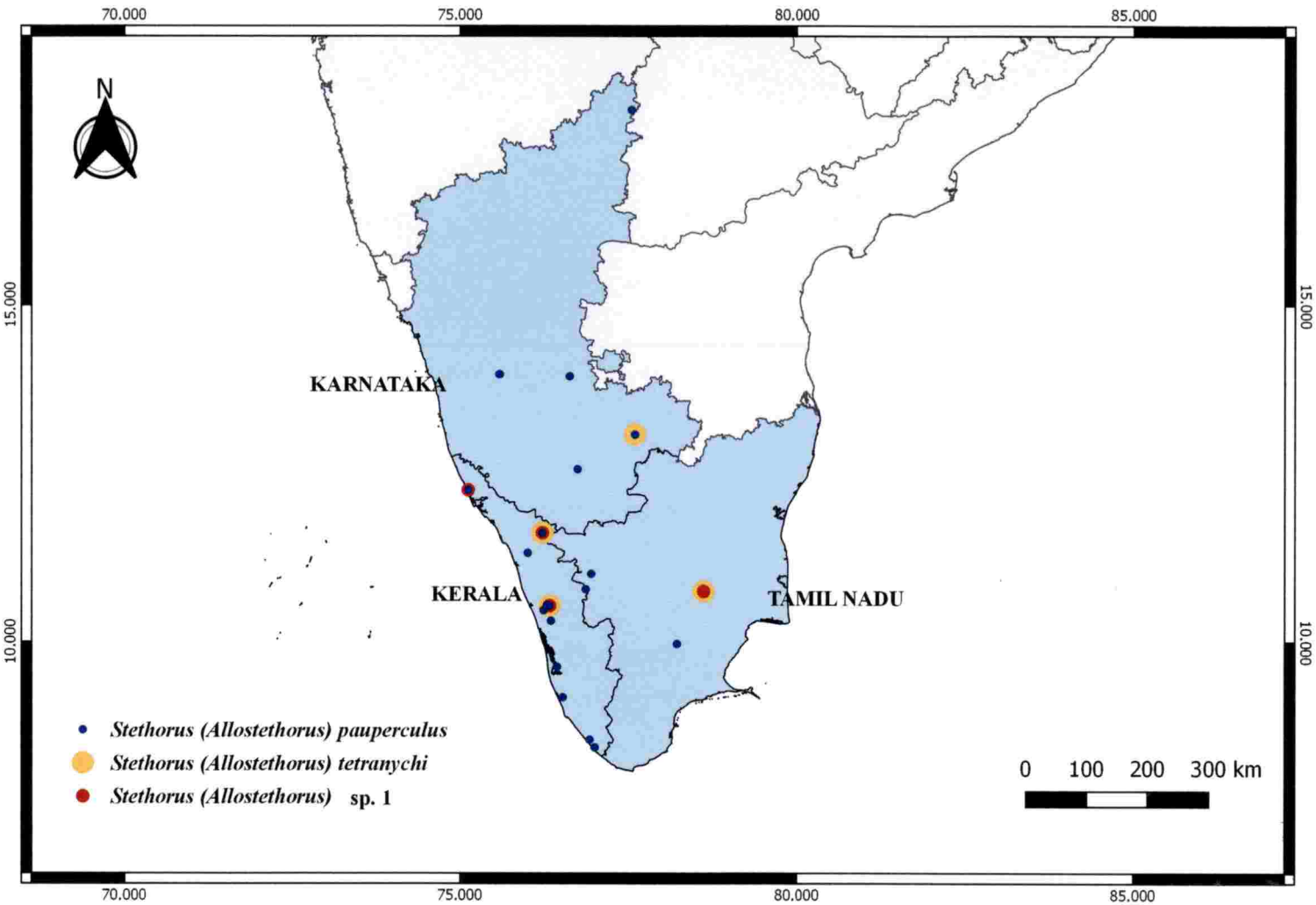


Fig. 44b. Distribution of species of Stethorini

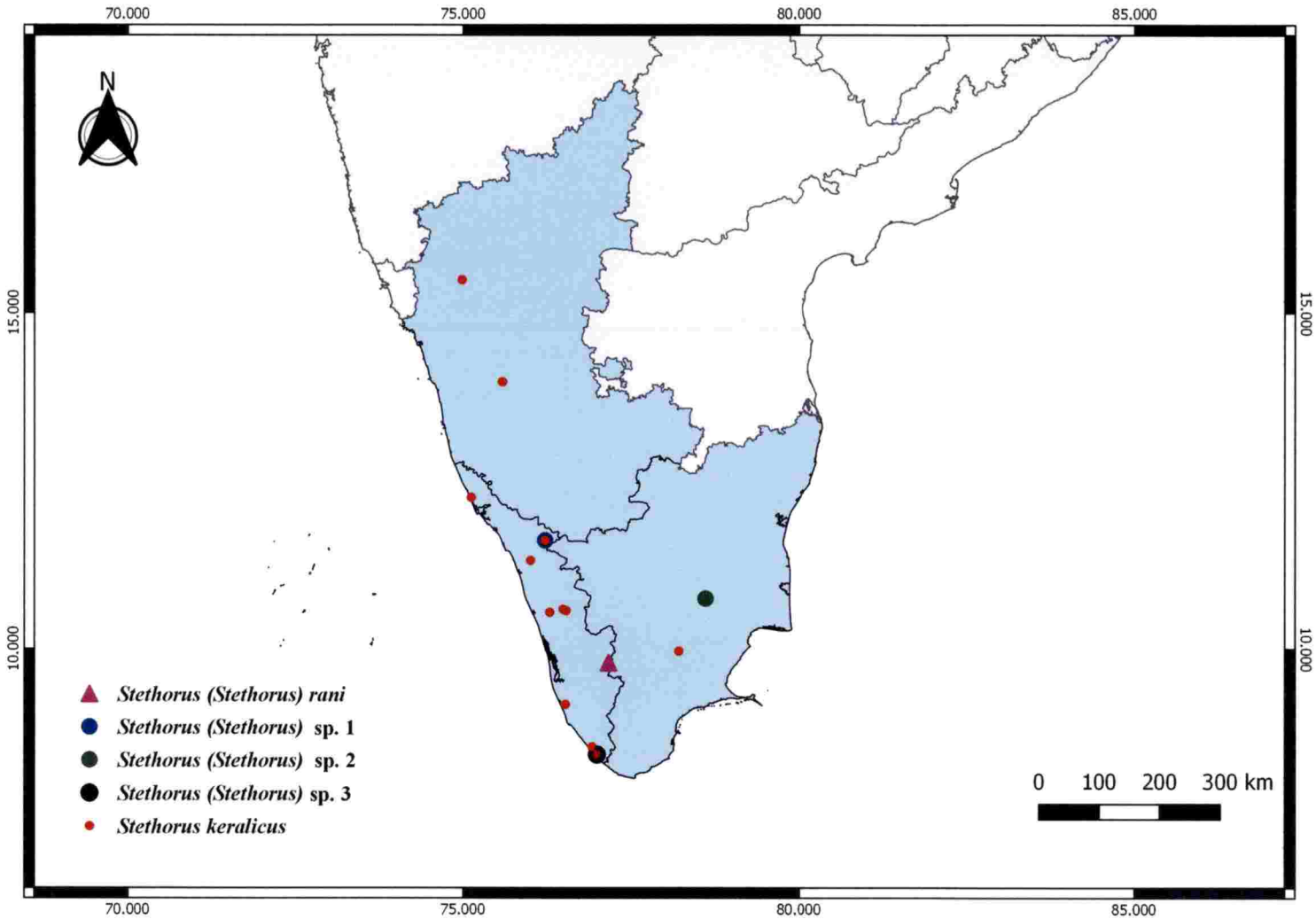


Fig. 44c. Distribution of species of Stethorini

Stethorus (*Allostethorus*) sp.1	*Tetranychus* sp.	**Kerala:** Ambalavayal, Marakkal, Padannakkad; **Tamil Nadu:** Tiruchirappalli
Stethorus (*Stethorus*) *rani* Kapur	*Tetranychus* sp.	**Kerala:** Pampadumpara
Stethorus (*Stethorus*) sp. 1	*Brevipalpus phoenicis*	Ambalavayal
Stethorus (*Stethorus*) sp. 2	*Tetranychus* sp.	Tiruchirappalli
Stethorus (*Stethorus*) sp. 3	Prey not known	Vellayani
Stethorus keralicus Kapur	*Raoiella indica*	**Kerala:** Ambalavayal, Kayamkulam, Mukkam, Padannakkad, Sreekaryam, Vadakkenchery, Vandazhy, Vellanikkara, Vellayni; **Karnataka:** Dharwad, Shivamogga; **Tamil Nadu:** Madurai, Tiruchirappalli

4. 2. DNA Barcoding of Stethorini

4. 2. 1. Quality of DNA

Total genomic DNA was isolated from 21 accessions of Stethorini which comprised of nine species from different locations. The concentration of DNA varied between 3.78-16.65 ng/µl (Table 9).

Table 9. Quality and quantity of isolated DNA

Species	Accession number	A260/A280	Concentration (ng/µl)
Parastethorus indira	TPAMA	1.84	16.49
Parastethorus indira	TTRCA	1.97	15.64
Parastethorus indira	TNMCA	1.86	14.41
S. (Allostethorus) forficatus	KMPTV	1.87	12.93
S. (Allostethorus) forficatus	KTVPA	1.98	6.52
S. (Allostethorus) forficatus	KTAPS	1.81	11.56
S. (Allostethorus) forficatus	KABG	1.97	5.43
S. (Allostethorus) pauperculus	KARAU	1.99	6.33
S. (Allostethorus) pauperculus	KALKY	1.94	4.49
S. (Allostethorus) tetranychi	KABGBN	1.90	16.65
S. (Allostethorus) sp. 1	TTR	1.97	9.82
S. (Allostethorus) sp. 1	AMCO	1.84	9.81
S. (Stethorus) rani	KID	1.93	8.43
S. (Stethorus) rani	PPCD	1.82	5.51
S. (Stethorus) rani	CDIK	1.91	3.78
S. (Stethorus) sp. 1	WDPO	1.83	16.21
S. (Stethorus) sp. 1	KWAM	1.95	14.32
S. (Stethorus) sp. 2	TTRMU	1.91	9.80
Stethorus keralicus	VNAR	1.90	9.01
Stethorus keralicus	KPDVDAR	1.96	12.73
Stethorus keralicus	KTRVKAR	1.94	10.37

4. 2. 2. Mitochondrial cytochrome *c* oxidase amplification and sequencing of PCR product

The PCR amplification of 710-bp fragment of the mitochondrial cytochrome *c* oxidase subunit I of 21 accessions was done. The annealing temperature for the PCR reaction was 60.1^{0}C. The PCR product was then assessed

by agarose gel electrophoresis for the presence of amplicons. The single distinct band near to 700 bp confirmed the amplification of mitochondrial cytochrome *c* oxidase subunit I. The gel pictures were displayed in Plate 12. Both forward and reverse sequences of 21 accessions were got sequenced by Sanger dideoxy method at AgriGenom Labs. Pvt. Ltd., Cochin.

4. 2. 3. Sequence annotation

The forward and reverse sequences of each accessions were assembled. The length of forward, reverse sequences and contigs is furnished in Table 10.

Table. 10. Length of forward, reverse and contig sequences

Species	Accession number	Length of sequences (bp length)		
		Forward	Reverse	Contig
Parastethorus indira	TPAMA	642	643	676
Parastethorus indira	TTRCA	642	650	681
Parastethorus indira	TNMCA	640	640	686
S. (Allostethorus) forficatus	KMPTV	648	649	681
S. (Allostethorus) forficatus	KTVPA	641	638	689
S. (Allostethorus) forficatus	KTAPS	637	622	686
S. (Allostethorus) forficatus	KABG	654	652	693
S. (Allostethorus) pauperculus	KARAU	638	651	688
S. (Allostethorus) pauperculus	KALKY	639	652	689
S. (Allostethorus) tetranychi	KABGBN	642	638	688
S. (Allostethorus) sp. 1	TTR	650	646	704
S. (Allostethorus) sp. 1	AMCO	631	637	686
S. (Stethorus) rani	KID	616	652	657
S. (Stethorus) rani	PPCD	649	658	692
S. (Stethorus) rani	CDIK	635	609	675
S. (Stethorus) sp. 1	WDPO	641	638	688
S. (Stethorus) sp. 1	KWAM	639	625	687

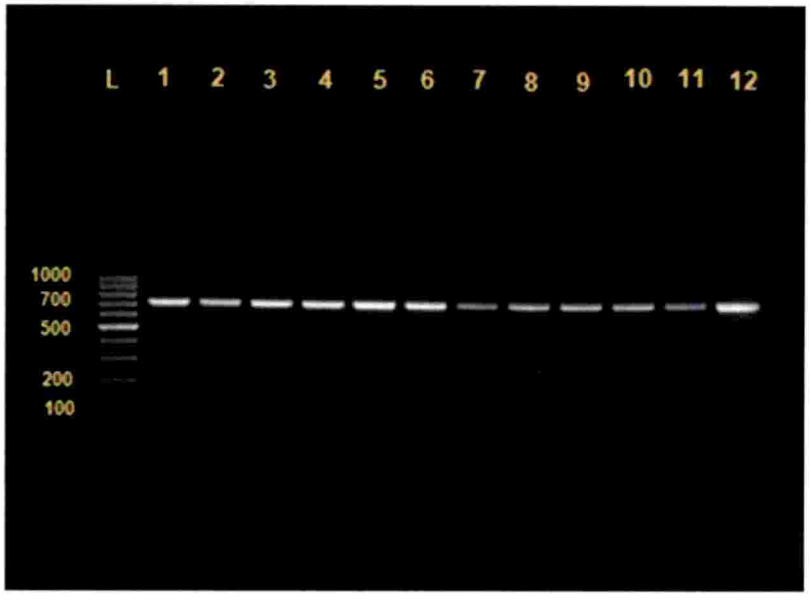


Plate. 12a. Amplification of *COI* locus

L-Ladder (100bp), 1- TPAMA; 2- TTRCA; 3- TNMCA; 4- KMPTV; 5-KTVPA; 6-KTAPS; 7-KABG; 8-KARAU; 9-KALKY; 10- KABGBN; 11- TTR; 12-AMCO

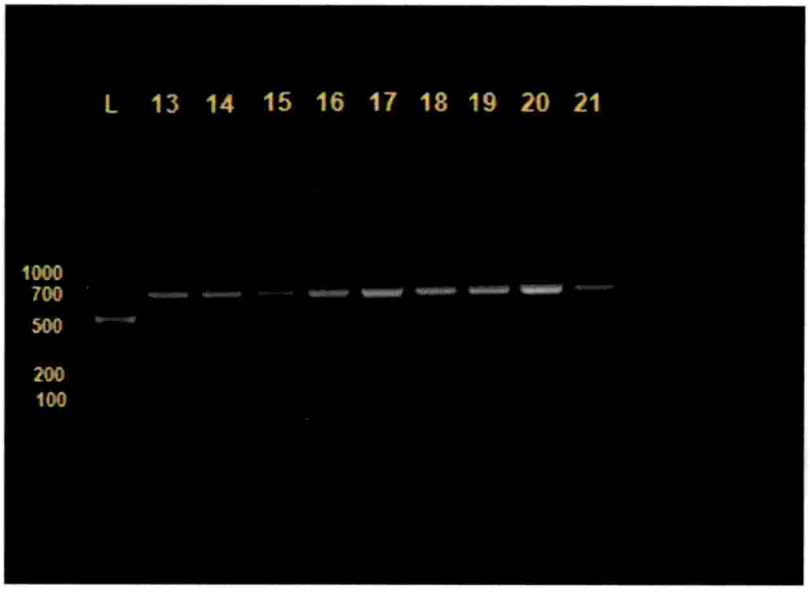


Plate. 12b. Amplification of *COI* locus

L-Ladder(100bp);13-KID; 14-PPCD; 15- CDIK; 16-WDPO; 17-KWAM; 18-TTRMU; 19-VNAR; 20-KPDVDAR;21- KTRVKAR

S. (*Stethorus*) sp. 2	TTRMU	634	633	680
Stethorus keralicus	VNAR	649	646	690
Stethorus keralicus	KPDVDAR	644	643	687
Stethorus keralicus	KTRVKAR	650	641	691

4. 2. 3. 1. Sequences of 21 accessions of the nine species of Stethorini

***Parastethorus indira* (TPAMA)**

GATATTGGAACCCTTTACTTCCTTTTTGGTTTATGAGCAGGAATAGTAGGAACCTCT
TTAAGAATTTTAATTCGTTTAGAATTAGGGACTCCTGGAACCCTTATTGGAAATGAC
CAAATTTATAATGTAATCGTAACTGCACATGCCTTTATTATAATTTTTTTCATAGTT
ATACCTATTATAATTGGCGGATTTGGGAACTGATTAGTACCTTTAATAATTGGAGCC
CCCGATATAGCTTTCCCTCGGCTTAATAACATGAGATTTTGGTTATTACCTCCTGCT
TTAACTTTGCTTCTCTTAGGAAGAGTTGTAGAAAGCGGGGCTGGCACTGGATGAAC
TGTTTATCCCCCCCTATCTAGAAATCTAGCTCATGGAGGATCAGCCGTAGATCTATC
AATTTTTAGATTACATTTAGCTGGTATTTCTTCTATTTTAGGAGCAGTAAATTTTATT
ACAACTATCATTAATATACGGCCTAATGGAATAACTTTAGAAAAAACTCCTTTATTT
GTTTGATCTGTTTTTATTACTGCCATTTTACTATTACTTTCTCTACCTGTATTAGCAG
GAGCAATTACTATATTATTAACAGACCGAAATATTAATACTACTTTTTTTGACCCAG
CAGGAGGGGGAGACCCTTTACTTTATCAACACTTATTTTGATTTTTTG

***Parastethorus indira* (TTRCA)**

TAAAGATATTGGAACCCTTTACTTCCTTTTTGGTTTATGAGCAGGAATAGTAGGAAC
CTCTTTAAGAATTTTAATTCGTTTAGAATTAGGGACTCCTGGAACCCTTATTGGAAA
TGACCAAATTTATAATGTAATCGTAACTGCACATGCCTTTATTATAATTTTTTTCAT
AGTTATACCTATTATAATTGGCGGATTTGGGAACTGATTAGTACCTTTAATAATTGG
AGCCCCCGATATAGCTTTCCCTCGGCTTAATAACATGAGATTTTGGTTATTACCTCC
TGCTTTAACTTTGCTTCTCTTAGGAAGAGTTGTAGAAAGCGGGGCTGGCACTGGAT
GAACTGTTTATCCCCCCCTATCTAGAAATCTAGCCCATGGAGGATCAGCCGTAGAT
CTATCAATTTTTAGATTACATTTAGCTGGTATTTCTTCTATTTTAGGAGCAGTAAATT
TTATTACAACTATCATTAATATACGGCCTAATGGAATAACTTTAGAAAAAACTCCTT
TATTTGTTTGATCTGTTTTTATTACTGCCATTTTACTATTACTTTCTCTACCTGTATTA
GCAGGAGCAATTACTATATTATTAACAGACCGAAATATTAATACTACTTTTTTTGAC
CCAGCAGGAGGGGGAGACCCTTTACTTTATCAACACTTATTTTGATTTTTTGG

***Parastethorus indira* (TNMCA)**

CATAAAGATATTGGAACCCTTTACTTCCTTTTTGGTTTATGAGCAGGAATAGTAGGA
ACCTCTTTAAGAATTTTAATTCGTTTAGAATTAGGGACTCCTGGAACCCTTATTGGA
AATGACCAAATTTATAATGTAATCGTAACTGCACATGCCTTTATTATAATTTTTTTC
ATAGTTATACCTATTATAATTGGCGGATTTGGGAACTGATTAGTACCTTTAATAATT
GGAGCCCCCGATATAGCTTTCCCTCGACTTAATAACATAAGATTTTGGTTATTACCT
CCTGCTTTAACTTTGCTTCTCTTAGGAAGAGTTGTAGAAAGCGGGGCTGGCACTGG
ATGAACTGTTTATCCCCCCCTATCTAGAAATCTAGCTCATGGAGGATCAGCCGTAG
ATCTATCAATTTTTAGATTACATTTAGCTGGTATTTCTTCTATTTTAGGAGCAGTAA
ATTTTATTACAACTATCATTAATATACGGCCTAATGGAATAACTTTAGAAAAAACT
CCTTTATTTGTTTGATCTGTTTTTATTACTGCCATTTTACTATTACTTTCTCTACCTGT
ATTAGCAGGAGCAATTACTATATTGTTAACAGACCGAAATATTAATACTACTTTTTT
TGACCCAGCAGGAGGGGGAGACCCTTTACTTTATCAACACTTATTTTGATTTTTTGG
TCA

212

***Stethorus* (*Allostethorus*) *forficatus* (KMPTV)**

AAAGATATTGGAACTTTATATTTTATTTTTGGTCTATGGGCAGGAATGGTAGGAACT
TCCTTAAGAATACTTATTCGATTAGAATTAGGAACTCCAGGAACTTTAATTGGAAA
TGATCAAATTTACAATGTAATCGTCACAGCTCATGCTTTTATCATAATTTTTTTTATA
GTAATACCTATTATAATTGGGGGATTTGGAAATTGATTGGTCCCTTTAATAATTGGG
GCTCCTGATATAGCTTTCCCACGTTTAAATAATATAAGATTTTGATTATTACCTCCT
GCTTTAACTTTATTAATTCTAGGAAGAATAGTAGAAAGAGGAGCAGGAACAGGAT
GAACAGTTTACCCTCCATTATCAAGAAATTTAGCACATGGAGGCTCAGCTGTTGAT
CTTTCAATTTTTAGACTTCACTTAGCTGGAATCTCTTCAATTTTAGGAGCAGTCAAT
TTTATTACAACTATCATTAATATACGGCCTTCAGGAATATCATTAGATAAAACTCCT
TTATTTGTTTGATCTGTTTTTATCACAGCAATTCTATTACTTCTTTCTTTACCAGTATT
AGCGGGAGCTATTACTATGCTTTTAACTGATCGAAATATTAATACTACATTCTTTGA
CCCTGCTGGAGGAGGAGACCCTCTTCTTTATCAACATTTATTTTGATTTTTTGGC

***Stethorus* (*Allostethorus*) *forficatus* (KTVPA)**

CATAAAGATATTGGAACTTTATATTTTATTTTTGGTCTATGGGCAGGAATGGTAGGA
ACTTCCTTAAGAATACTTATTCGATTAGAATTAGGAACTCCAGGAACTTTAATTGG
AAATGATCAAATTTACAATGTAATCGTCACAGCTCATGCTTTTATCATAATTTTTTT
TATAGTAATACCTATTATAATTGGGGGATTTGGAAATTGATTGGTCCCTTTAATAAT
TGGGGCTCCTGATATAGCTTTCCCACGTTTAAATAATATAAGATTTTGATTATTACC
TCCTGCTTTAACTTTATTAATTCTAGGAAGAATAGTAGAAAGAGGAGCAGGAACAG
GATGAACAGTTTACCCTCCATTATCAAGAAATTTAGCACATGGAGGCTCAGCTGTT
GATCTTTCAATTTTTAGACTTCACTTAGCTGGAATTTCTTCAATTTTAGGAGCAGTC
AATTTTATTACAACTATCATTAATATACGACCTTCAGGAATATCATTAGATAAAACT
CCTTTATTTGTTTGGTCTGTTTTTATCACAGCAATTCTTTTACTTCTTTCTTTACCAGT
ATTAGCGGGAGCTATTACTATGCTTTTAACTGATCGAAATATTAATACTACATTCTT
TGACCCTGCTGGAGGAGGAGACCCTCTTCTTTATCAACATTTATTTTGATTTTTTGG
TCACCT

***Stethorus* (*Allostethorus*) *forficatus* (KTAPS)**

TAAAGATATTGGAACTTTATATTTTATTTTTGGTCTATGGGCAGGAATGGTAGGAAC
TTCCTTAAGAATACTTATTCGATTAGAATTAGGAACTCCAGGAACTTTAATTGGAA
ATGATCAAATTTACAATGTAATCGTCACAGCTCATGCTTTTATCATAATTTTTTTTAT
AGTAATACCTATTATAATTGGGGGATTTGGAAATTGATTGGTCCCTTTAATAATTGG
GGCTCCTGATATAGCTTTCCCACGTTTAAATAATATAAGATTTTGATTATTGCCTCC
TGCTTTAACTTTATTAATTCTAGGAAGAATAGTAGAAAGAGGAGCAGGAACAGGAT
GAACAGTTTACCCTCCATTATCAAGAAATTTAGCACATGGAGGCTCAGCTGTTGAT
CTTTCAATTTTTAGACTTCACTTAGCTGGAATCTCTTCAATTTTAGGAGCAGTCAAT
TTTATTACAACTATCATTAATATACGACCTTCAGGAATATCATTAGATAAAACTCCT
TTATTTGTTTGATCTGTTTTTATCACAGCAATTCTATTACTTCTTTCTTTACCAGTATT
AGCGGGAGCTATTACTATGCTTTTAACTGATCGAAATATTAATACTACATTCTTTGA
CCCTGCTGGAGGAGGAGACCCTCTTCTTTATCAACATTTATTTTGATTTTTTGGTCA
CC

213

***Stethorus* (*Allostethorus*) *forficatus* (KABG)**

CATAAAGATATTGGAACTTTATATTTTATTTTTGGTCTATGGGCAGGAATGGTAGGA
ACTTCCTTAAGAATACTTATTCGATTAGAATTAGGAACTCCAGGAACTTTAATTGG
AAATGATCAAATTTACAATGTAATCGTCACAGCTCATGCTTTTATCATAATTTTTTT
TATAGTAATACCTATTATAATTGGGGGATTTGGAAATTGATTGGTCCCTTTAATAAT
TGGGGCTCCTGATATAGCTTTCCCACGTTTAAATAATATAAGATTTTGATTATTACC
TCCTGCTTTAACTTTATTAATTCTAGGAAGAATAGTAGAAAGAGGAGCAGGAACAG
GATGAACAGTTTACCCTCCATTATCAAGAAATTTAGCACATGGAGGCTCAGCTGTT
GATCTTTCAATTTTTAGACTTCACTTAGCTGGAATCTCTTCAATTTTAGGAGCAGTC
AATTTTATTACAACTATCATTAATATACGGCCTTCAGGAATATCATTAGATAAAACT
CCTTTATTTGTTTGATCTGTTTTTATCACAGCAATTCTATTACTTCTTTCTTTACCAGT
ATTAGCGGGAGCTATTACTATGCTTTTAACTGATCGAAATATTAATACTACATTCTT
TGACCCTGCTGGAGGAGGAGACCCTCTTCTTTATCAACATTTATTTTGATTTTTTGG
TCACCCTGAA

***Stethorus* (*Allostethorus*) *pauperculus* (KARAU)**

CATAAAGATATTGGAACATTATATTTCATTTTTGGTTTATGAGCTGGAATAGTTGGA
ACTTCCTTAAGAATGTTAATTCGTTTAGAATTAGGCACTCCTGGTACTTTAATTGGG
AATGACCAAATTTACAACGTAATTGTGACAGCTCATGCATTTATTATAATTTTCTTT
ATAGTTATACCAATTATAATTGGCGGATTTGGAAATTGACTTGTCCCTTTAATAATT
GGAGCTCCTGATATAGCATTCCCTCGCTTAAATAACATAAGATTTTGATTACTCCCT
CCGGCTTTAACTTTACTAATTTTAGGAAGAATAGTAGAAAGAGGAGCAGGGACTGG
CTGAACAGTTTACCCTCCATTATCAAGAAATTTAGCTCATGGAGGATCCGCTGTAG
ATTTATCAATTTTTAGATTACATTTAGCTGGAATCTCTTCTATTTTAGGGGCTGTAA
ATTTTATTACAACTATCATTAATATACGCCCAACTGGAATAACACTAGATAAAACT
CCTCTTTTTGTTTGATCGGTATTTATTACTGCTATTTTATTACTTTTATCTTTACCCGT
TTTAGCAGGGGCTATTACTATGCTTCTTACAGATCGAAATATTAATACTACTTTTTT
TGACCCCGCAGGAGGAGGAGACCCTCTTCTTTACCAGCATTTATTTTGATTTTTTGG
TCACC

***Stethorus* (*Allostethorus*) *pauperculus* (KALKY)**

CATAAAGATATTGGAACATTATATTTCATTTTTGGTTTATGAGCTGGAATAGTTGGA
ACTTCTTTAAGAATATTAATTCGTTTAGAATTAGGCACTCCTGGTACTTTAATTGGA
AATGACCAAATTTACAATGTAATTGTAACAGCTCATGCATTTATTATAATTTTCTTT
ATAGTTATACCAATTATAATTGGCGGATTTGGAAATTGACTTGTCCCTTTAATAATT
GGGGCTCCTGATATAGCATTCCCTCGCTTAAATAACATAAGATTTTGATTACTCCCT
CCAGCTCTAACTTTACTAATTTTAGGAAGAATGGTAGAAAGAGGGGCAGGGACTG
GTTGAACAGTTTACCCTCCATTATCAAGAAATTTAGCTCATGGAGGATCCGCTGTA
GATTTATCAATTTTTAGATTACATTTAGCTGGAATCTCTTCTATTTTAGGGGCTGTA
AATTTTATTACAACTATCATTAATATACGCCCAACTGGAATAACACTAGATAAAAC
TCCTCTTTTTGTTTGATCGGTATTTATTACTGCTATTTTATTACTTTTATCTTTACCTG
TTTTAGCAGGGGCTATTACTATACTTCTTACAGATCGAAATATTAATACTACTTTTT
TTGACCCCGCAGGAGGAGGAGACCCTCTTCTTTACCAGCATTTATTTTGATTTTTTG
GTCACCT

214

***Stethorus* (*Allostethorus*) *tetranychi* (KABGBN)**

ATAAAGATATTGGAACTCTTTATTTTATATTTGGGCTTTGAGCTGGAATAGTAGGAA
CTTCTTTAAGAATTCTTATTCGTTTAGAATTAGGTTCTCCAGGTTCATTAATTGGGA
ATGACCAAATTTATAATGTAATTGTAACAGCACATGCTTTCATTATAATTTTTTTTA
TAGTTATACCTATCATAATTGGAGGATTTGGAAACTGGCTTGTGCCTTTAATAATTG
GGGCCCCAGATATAGCTTTCCCTCGTTTAAATAACATAAGATTTTGACTTTTACCAC
CTGCTTTAACTTTACTAATTTTAGGAAGAATAGTAGAAAGAGGGGCTGGGACAGGA
TGAACTGTTTATCCACCTTTATCTAGAAATTTAGCTCATGGAGGTTCAGCTGTAGAT
CTTTCAATTTTTAGACTTCACTTAGCTGGAATTTCTTCTATTTTGGGAGCTGTCAATT
TTATTACAACTATTATCAATATACGACCTACTGGAATAACATTGGACAAAACTCCTT
TATTTGTATGATCAGTTTTTATTACTGCAATTCTTTTACTTCTTTCTTTACCTGTTTTA
GCTGGAGCTATCACAATACTTTTAACAGATCGAAATATTAATACTACTTTTTTTGAC
CCAGCAGGAGGAGGAGATCCTTTATTATACCAACATTTATTCTGATTTTTTGGTCAC
CT

***Stethorus* (*Allostethorus*) sp. 1 (TTR)**

AACAAATCATAAAGATATTGGAACTCTATACTTTATTTTTGGCCTATGAGCAGGAA
TAGTCGGAACTTCATTAAGAATACTAATTCGCCTAGAATTAGGAACCCCAGGAACT
CTGATCGGGAATGATCAAATTTACAATGTGATTGTGACTGCTCATGCATTTATCATA
ATTTTTTTTATAGTAATACCAATTATAATTGGAGGATTTGGAAATTGATTAGTGCCT
TTAATAATTGGGGCTCCAGATATAGCTTTTCCTCGCTTAAATAATATAAGATTTTGA
CTTTTACCTCCTGCCTTAACTCTACTAATTTTAGGAAGAATAGTAGAAAGAGGGGC
CGGGACAGGTTGAACAGTTTACCCTCCCTTATCGAGAAATTTAGCTCATGGAGGAT
CAGCAGTTGATTTATCAATTTTTAGATTACATTTAGCAGGGATTTCATCTATTTTAG
GAGCTGTAAATTTCATTACAACCATTATTAATATACGCCCAACAGGAATAACCTTA
GATAAAACTCCTTTATTTGTATGATCAGTTTTTATTACAGCTATTTTACTTTTATTAT
CTTTACCTGTATTAGCTGGGGCTATTACTATACTTTTAACTGACCGAAATATTAATA
CTACTTTTTTTGACCCTGCTGGAGGGGGGGATCCCCTTCTTTACCAACACTTATTTT
GATTTTTTGGTCACCCTGGAAGTT

***Stethorus* (*Allostethorus*) sp. 1 (AMCO)**

TAAAGATATTGGAACTCTATACTTTATTTTTGGTCTATGAGCAGGAATAGTCGGAA
CTTCATTAAGAATGCTAATTCGCCTAGAATTAGGAACCCCAGGAACTCTGATCGGA
AATGATCAAATTTATAATGTGATTGTGACTGCCCATGCTTTTATCATAATTTTTTTTA
TAGTAATACCAATTATAATTGGAGGATTTGGAAATTGATTAGTGCCTTTAATAATTG
GAGCTCCAGATATAGCTTTTCCTCGCTTAAATAATATAAGATTTTGACTTTTACCTC
CTGCCTTAACTCTACTAATTTTAGGAAGAATAGTAGAAAGAGGGGCCGGAACAGGT
TGAACAGTTTACCCTCCCTTATCAAGAAATTTAGCTCATGGGGGGTCAGCAGTTGA
TTTATCAATTTTTAGATTACATTTAGCAGGGATTTCATCTATTTTAGGGGCTGTAAA
TTTCATTACAACCATTATTAATATACGCCCAACAGGAATAACCTTAGATAAAACTC
CTTTATTTGTATGATCAGTTTTTATTACAGCTATTTTACTTTTATTATCTTTACCTGTA
TTAGCTGGAGCTATTACTATACTTTTAACTGACCGAAATATTAATACTACTTTTTTT
GACCCTGCTGGAGGAGGAGATCCTCTTCTTTACCAACACTTATTTTGATTTTTTGGT
CACC

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***Stethorus* (*Stethorus*) *rani* (KID)**

CATAAAGATATTGGTACTCTATATTTTCTCTTTGGTTTATGAGCTGGAATAGTAGGA
ACATCTTTAAGAATTTTAATTCGTCTTGAATTAGGAACTCCTGGATCTTTAATTGGA
AATGATCAAATTTACAATGTTATTGTTACAGCTCATGCTTTCATCATAATTTTTTTTA
TAGTCATACCAATTATAATCGGAGGGTTTGGAAACTGATTAGTGCCTTTAATAATT
GGAGCTCCCGATATAGCTTTCCCTCGTCTAAATAACATAAGATTTTGACTTCTCCCT
CCTGCTTTAACTCTTCTTATTTTAGGAAGAATAGTAGAAAGAGGAGCTGGAACTGG
ATGAACTGTTTATCCTCCTTTATCTAGAAATTTAGCCCATGGGGGTTCAGCAGTAGA
TTTATCTATTTTTAGTCTTCATTTAGCTGGGATCTCATCAATCTTAGGGGCCGTAAA
TTTTATTACTACAATTATTAATATACGACCTATAGGAATAACATTAGACAAAACTCC
CTTATTTGTTTGATCAGTTTTTATTACTGCAATTTTACTTCTTCTATCTCTTCCTGTTT
TAGCAGGAGCAATTACTATACTTTTGACAGACCGAAATATTAATACAACTTTTTTCG
ATCCTGCAGGAGGAGGAGACCCCCTTTTA

***Stethorus* (*Stethorus*) *rani* (PPCD)**

AAAATCATAAAGATATTGGTACTCTATATTTTCTCTTTGGTTTATGAGCTGGAATAG
TAGGAACATCTTTAAGAATTTTAATTCGTCTTGAATTAGGAACTCCTGGATCTTTAA
TTGGAAATGATCAAATTTACAATGTTATTGTTACAGCTCATGCTTTCATCATAATTT
TTTTTATAGTCATACCAATTATAATCGGAGGGTTTGGAAACTGATTAGTGCCTTTAA
TAATTGGAGCTCCCGATATAGCTTTCCCTCGTCTAAATAACATAAGATTTTGACTTC
TCCCTCCTGCTTTAACTCTTCTTATTTTAGGAAGAATAGTAGAAAGAGGAGCTGGA
ACTGGATGAACTGTTTATCCTCCTTTATCTAGAAATTTAGCCCATGGGGGTTCAGCA
GTAGATTTATCTATTTTTAGTCTTCATTTAGCTGGGATCTCATCAATCTTAGGGGCC
GTAAATTTTATTACTACAATTATTAATATACGACCTATAGGAATAACATTAGACAA
AACTCCCTTATTTGTTTGATCAGTTTTTATTACTGCAATTTTACTTCTTCTATCTCTTC
CTGTTTTAGCAGGAGCAATTACTATACTTTTGACAGACCGAAATATTAATACAACTT
TTTTCGATCCTGCAGGAGGAGGAGACCCCCTTTTATACCAACATTTATTTTGATTTT
TTGGTCAC

***Stethorus* (*Stethorus*) *rani* (CDIK)**

ACTCTATATTTTCTCTTTGGTTTATGAGCATGGAATAGTAGGAACATCTTTAAGAAT
TTTAATTCGTCTTGAATTAGGAACCCCTGGATCTTTAATTGGAAATGATCAAATTTA
CAATGTTATTGTTACAGCTCATGCTTTCATCATAATTTTTTTTATAGTCATACCAATT
ATAATCGGAGGGTTTGGAAACTGATTAGTGCCTTTAATAATTGGAGCTCCCGATAT
AGCTTTCCCTCGTCTAAATAACATAAGATTTTGACTTCTCCCTCCTGCTTTAACTCTT
CTTATTTTAGGAAGAATAGTAGAAAGAGGAGCTGGAACTGGATGAACTGTTTATCC
TCCTTTATCTAGAAATTTAGCCCATGGGGGTTCAGCAGTAGATTTATCTATTTTTAG
TCTTCATTTAGCTGGGATCTCATCAATCTTAGGGGCCGTAAATTTTATTACTACAAT
TATTAATATACGACCTATAGGAATAACATTAGACAAAACTCCCTTATTTGTTTGATC
AGTTTTTATTACTGCAATTTTACTTCTTCTATCTCTTCCGGTTTTACCAGGAGCAATT
ACTATACTTTTGACAGACCGAAATATTAATACAACTTTTTTCGATCCTGCAGGAGG
AGGAGACCCTCCTTTTATACCAACATTTATTTTGATTTTTTGGTCACT

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***Stethorus* (*Stethorus*) sp. 1 (WDPO)**

ATAAAGATATTGGTACTTTATATTTTATTTTTGGTCTATGGGCTGGAATAGTAGGAA
CATCATTGAGAATTTTAATCCGGCTTGAATTAGGAACACCTGGATCTTTAATTGGTA
ACGATCAAATTTATAATGTGATTGTTACAGCCCATGCTTTTATCATAATTTTTTTCAT
AGTAATACCAATTATAATTGGTGGATTTGGAAATTGGTTAGTACCCTTAATAATTG
GAGCTCCAGATATAGCATTCCCTCGACTTAATAATATAAGATTTTGGCTTTTACCTC
CCGCCCTGACTCTTCTAATCTTAGGAAGAATGGTGGAAAGAGGAGCTGGGACCGG
ATGAACTGTATACCCTCCTTTATCTAGAAACTTGGCTCATGGAGGGTCAGCAGTAG
ATCTATCTATTTTCAGCCTTCATTTAGCTGGAATTTCCTCCATTCTAGGAGCTGTTAA
TTTTATCACTACTATCATCAATATACGGCCTGTAGGAATGACCTTAGATAAGACTCC
ACTATTTGTGTGATCAGTACTTATTACTGCAATTTTACTACTCTTATCACTCCCAGTG
TTAGCTGGAGCTATTACTATACTTTTAACAGATCGAAATATTAACACAACTTTTTTT
GACCCAGCAGGAGGAGGAGATCCTTTATTATACCAACATTTATTTTGATTTTTTGGT
CACCT

***Stethorus* (*Stethorus*) sp. 1 (KWAM)**

CATAAAGATATTGGTACTTTATATTTTATTTTTGGTCTATGGGCTGGAATAGTAGGA
ACATCATTGAGAATTTTAATCCGGCTTGAATTAGGAACACCTGGATCTTTAATTGGT
AACGATCAAATTTATAATGTGATTGTTACAGCCCATGCTTTTATCATAATTTTTTTC
ATAGTAATACCAATTATAATTGGTGGATTTGGAAATTGGTTAGTACCCTTAATAATT
GGAGCTCCAGATATAGCATTCCCTCGACTTAATAATATAAGATTTTGGCTTTTACCT
CCCGCCCTGACTCTTCTAATCTTAGGAAGAATGGTGGAAAGAGGAGCTGGGACCGG
ATGAACTGTATACCCTCCTTTATCTAGAAACTTGGCTCATGGAGGGTCAGCAGTAG
ATCTATCTATTTTCAGCCTTCATTTAGCTGGAATTTCCTCCATTCTAGGAGCTGTTAA
TTTTATCACTACTATCATCAATATACGGCCTGTAGGAATGACCTTAGATAAGACTCC
ACTATTTGTGTGATCAGTACTTATTACTGCAATTTTACTACTCTTATCACTCCCAGTG
TTAGCTGGAGCTATTACTATACTTTTAACAGATCGAAATATTAACACAACTTTTTTT
GACCCAGCAGGAGGAGGAGATCCTTTATTATACCAACATTTATTTTGATTTTTTGGT
CAC

***Stethorus* (*Stethorus*) sp. 2 (TTRMU)**

AAGATATTGGAACCTTATATTTTTTATTTGGATTATGGGCAGGAATAGTGGGCACA
TCTTTAAGAATTTTAATTCGTTTAGAATTAGGGACCCCAGGATCATTAATTGGGAAT
GATCAAATTTACAATGTAATTGTAACTTCACACGCTTTCATTATAATTTTTTTTATA
GTAATACCAATTATAATCGGGGGATTCGGAAATTGGCTTGTGCCTCTAATAATTGG
GGCGCCTGATATAGCTTTCCCTCGATTAAATAATTTAAGATTTTGACTTTTACCCCC
AGCCTTAACCCTACTACAACTAAGAAGAATAGTAGAAAGAGGTGCTGGAACAGGC
TGAACTATTTACCCGCCTTTATCTAGAAATATTGCCCATAGAGGCCCAGCTGTTGAT
CTTTCTATTTTTAGTTTACATCTAGCGGGGATTTCTTCAATTTTAGGAGCTATCAATT
TTATTACAACTATTATTAATATACGACCAGCTGGAATAACGTGAGATAAGGTGCCT
TTATTTGTATGATCAGTATTTATTACTGCAATTTTACTTTTACTTTCTTTACCTGTATT
AGCAGGAGCTATCACTATACTTTTAACTGATCGAAATATTAATACAACTTTCTTTGA
CCCGGCAGGAGGTGGAGATCCTCTTTTATACCAGCACTTATTTTGATTTTTTGGT

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***Stethorus keralicus* (VNAR)**

CATAAAGATATTGGAACCTTATATTTTTTATTTGGATTATGGGCAGGATTAGTGGGC
ACATCTTTGAGAATTTTAATTCGTTTAGAATTAGGGACCCCAGGATCATTAATTGGG
AATGATCAAATTTACAATGTAATTGTAACTTCACACGCTTTCATTATAATTTTTTTT
ATAGTAATACCAATTATAATCGGGGGGTTCGGAAATTGACTTGTGCCTCTAATAAT
TGGGGCGCCTGATATAGCTTTCCCTCGATTAAATAATTTAAGATTTTGACTTTTACC
CCCAGCCTTAAGCCTACTACAACTAAGAAGAATAGTAGAAAGAGGTGCTGGAACA
GGCTGAACTATTTACCCGCCTTTATCTAGAAATATTGCCCATAGAGGCCCAGCTGTT
GATCTTTCTATTTTTAGTTTACACCTAGCGGGGATTTCTTCAATTTTAGGAGCTATC
AATTTTATTACAACTATTATTAATATACGACCAGCTGGGATAAGGTGAGATAAGGT
GCCTTTATTTGTATGATCAGTATTTATTACTGCAATTTTACTTTTACTTTCTTTACCT
GTATTAGCAGGAGCTATCACTATACTTTTAACTGATCGAAATATTAATACAACTTTT
TTTGACCCGGCAGGAGGTGGAGATCCTCTTTTATACCAGCACTTATTTTGATTTTTT
GGTCACCTT

***Stethorus keralicus* (KPDVDAR)**

CATAAAGATATTGGAACCTTATATTTTTTATTTGGATTATGGGCAGGATTAGTGGGC
ACATCTTTAAGAATTTTAATTCGTTTAGAATTAGGGACCCCGGGATCATTAATTGGG
AATGATCAAATTTACAATGTAATTGTAACTTCACACGCTTTCATTATAATTTTTTTT
ATAGTAATACCAATTATAATCGGGGGGTTCGGAAATTGGCTTGTGCCTCTAATAAT
TGGGGCGCCTGATATAGCTTTCCCTCGATTAAATAATTTAAGATTTTGACTTTTACC
CCCAGCCTTAAGCCTACTACAACTAAGAAGAATGGTAGAAAGAGGTGCTGGAACA
GGCTGAACTATTTACCCGCCTTTATCTAGAAATATTGCCCATAGAGGCCCAGCTGTT
GATCTTTCTATTTTTAGTTTACATCTAGCGGGGATTTCTTCAATTTTAGGAGCTATCA
ATTTTATTACAACTATTATTAATATACGACCAGCTGGGATAAGGTGAGATAAGGTG
CCTTTATTTGTATGATCAGTATTTATTACTGCAATTTTACTTTTACTTTCTTTACCTGT
ATTAGCAGGAGCTATCACTATACTTTTAACTGATCGAAATATTAATACAACTTTTTT
TGACCCGGCAGGAGGTGGAGATCCTCTTTTATACCAGCACTTATTTTGATTTTTTGG
TCAC

***Stethorus keralicus* (KTRVKAR)**

CATAAAGATATTGGAACCTTATATTTTTTATTTGGATTATGGGCAGGATTAGTGGGC
ACATCTTTAAGAATTTTAATTCGTTTAGAATTAGGGACCCCGGGATCATTAATTGGG
AATGATCAAATTTACAATGTAATTGTAACTTCACACGCTTTCATTATAATTTTTTTT
ATAGTAATACCAATTATAATCGGGGGGTTCGGAAATTGACTTGTGCCTCTAATAAT
TGGGGCGCCTGATATAGCTTTCCCTCGATTAAATAATTTAAGATTTTGACTTTTACC
CCCAGCCTTAAGCCTACTACAACTAAGAAGAATGGTAGAAAGAGGTGCTGGAACA
GGCTGAACTATTTACCCGCCTTTATCTAGAAATATTGCCCATAGAGGCCCAGCTGTT
GATCTTTCTATTTTTAGTTTACATCTAGCGGGGATTTCTTCAATTTTAGGAGCTATCA
ATTTTATTACAACTATTATTAATATACGACCAGCTGGGATAAGGTGAGATAAGGTG
CCTTTATTTGTATGATCAGTATTTATTACTGCAATTTTACTTTTACTTTCTTTACCTGT
ATTAGCAGGAGCTATCACTATACTTTTAACTGATCGAAATATTAATACAACTTTTTT
TGACCCGGCAGGAGGTGGAGATCCTCTTTTATACCAGCACTTATTTTGATTTTTTGG
TCACCTGG

4. 2. 4. Sequence homology

Homology analysis showed that the locus of interest, mitochondrial cytochrome oxidase *c* was amplified in all the accessions. None of the query sequences, except that of three accessions of *P. indira*, showed >90 per cent similarity with the available sequences. *P. indira* showed 95 per cent similarity with one coccinellid species.

Per cent homology of the 21 accessions generated with NCBI database is furnished below (Table 11). First three hits generated to each sequence query is included.

4. 2. 5. Barcode gap

Barcode gaps were identified by aligning the sequences of 21 accessions and summarised manually (Fig 45 and 46). The position of the nucleotide in the gene was determined by aligning these sequences with the complete genome of mtCOI of *Henosepilachna pusillanima* retrieved from GenBank which had a length of 1540bp.

4. 2. 6. Pairwise distances of sequences

The intraspecific and interspecific distances of 19 accessions are furnished below (Table 12). The table represents genetic distances between sequences. The intraspecific distances varied from 0.00 to 0.03 whereas the interspecific distances varied from 0.14 to 0.24.

4. 2. 7. Phylogenetic tree

The phylogenetic tree was constructed for mtCOI locus of 21 sequences representing nine species of Stethorini, which is given below (Fig. 47).

The tree formed has three major clades, of which the first clade was represented by three species of *Stethorus* (*Allostethorus*) *viz.*, *S* (*A.*). *forficatus*, *S.* (*A.*) *pauperculus*, *S.* (*A.*) sp. 1 and *P. indira*. Second clade included two species of *Stethorus* (*Stethorus*) *viz.*, *S.* (*S.*) *rani* and *S.* (*S.*) sp. 1. The third clade was represented by *S.* (*A*). *tetranychi*,

Table 11. Per cent homology of sequences with NCBI database

	Hits generated to query sequences			
	Match in GenBank	Identity (%)	NCBI accession number	e value
Parastethorus indira (TPAMA) *Parastethorus indira* (TTRCA) *Parastethorus. indira* (TNMCA)	Coccinellidae sp. (cytochrome oxidase subunit 1 (*COI*) gene)	95	KY842548.1	0.0
	Coccinellidae sp. (cytochrome oxidase subunit 1 (*COI*) gene)	95	KY845023.1	0.0
	Coccinellidae sp. (cytochrome oxidase subunit 1 (*COI*) gene	95	KY843205.1	0.0
S. (Allostethorus) forficatus (KMPTV) *S. (Allostethorus) forficatus* (KABG)	*Scymnus abietis* (cytochrome oxidase subunit 1 (*COI*) gene)	86	KM447172.1	0.0
	Brumoides suturalis (cytochrome oxidase subunit 1 (*COI*) gene)	86	KY831199.1	0.0
	Scymnus abietis (cytochrome oxidase subunit 1 (*COI*) gene)	86	KM440635.1	0.0

S. (*Allostethorus*) *forficatus* (KTVPA)	*Scymnus abietis* (cytochrome oxidase subunit 1 (*COI*) gene)	86	KM447172.1	0.0
	Scymnus abietis (cytochrome oxidase subunit 1 (*COI*) gene)	86	KM440635.1	0.0
	Scymnus abietis (cytochrome oxidase subunit 1 (*COI*) gene)	86	KM448896.1	0.0
S. (*Allostethorus*) *forficatus* (KTAPS)	*Scymnus abietis* (cytochrome oxidase subunit 1 (*COI*) gene)	86	KM447172.1	0.0
	Scymnus abietis (cytochrome oxidase subunit 1 (*COI*) gene)	86	KM440635.1	0.0
	Brumoides suturalis (cytochrome oxidase subunit 1 (*COI*) gene)	86	KY831199.1	0.0
S.(*Allostethorus*) *pauperculus* (KARAU)	*Coccinellinae* sp. (cytochrome oxidase subunit 1 (*COI*) gene)	87	KR480942.1	0.0
	Epilachna admirabilis (mitochondrial *COI* gene for cytochrome oxidase subunit I)	85	AB002178.1	0.0

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	Epilachna sp. mitochondrial *COI* gene for cytochrome oxidase subunit I	85	AB002179.1	0.0
S. (*Allostethorus*) *pauperculus* (KALKY)	*Coccinellinae* sp. (cytochrome oxidase subunit 1 (*COI*) gene)	87	KR480942.1	0.0
	Epilachna sp. mitochondrial *COI* gene for cytochrome oxidase subunit I	85	AB002179.1	0.0
	Epilachna admirabilis (mitochondrial *COI* gene for cytochrome oxidase subunit I)	85	AB002178.1	0.0
S. (*Allostethorus*) *tetranychi* (KABGBN)	*Coccinellinae* sp. (cytochrome oxidase subunit 1 (*COI*) gene)	88	KR480942.1	0.0
	Stethorus sp. (cytochrome oxidase subunit 1 (*COI*) gene)	87	KY835905.1	0.0
	Stethorus sp. (cytochrome oxidase subunit 1 (*COI*) gene)	87	KY841434.1	0.0
S. (*Allostethorus*) sp. 1 (TTR)	*Chilocorus nigritus* (cytochrome oxidase subunit 1 (COI) gene)	86	KY842829.1	0.0

	Chilocorus nigritus (cytochrome oxidase subunit 1 (*COI*) gene)	86	KY831562.1	0.0
	Coccinellinae sp (cytochrome oxidase subunit 1 (*COI*) gene)	86	KR480942.1	0.0
S.(*Allostethorus*) sp. 1 (AMCO)	*Chilocorus nigritus* (cytochrome oxidase subunit 1 (*COI*) gene)	87	KY842829.1	0.0
	Chilocorus nigritus (cytochrome oxidase subunit 1 (*COI*) gene)	87	KY831562.1	0.0
	Chilocorus nigritus (cytochrome oxidase subunit 1 (*COI*) gene	87	KX051943.1	0.0
S. (*Stethorus*) *rani* (KID) & *S.* (*Stethorus*) *rani* (PPCD)	Coccinellinae sp. BOLD-2016 (cytochrome oxidase subunit 1 (*COI*) gene)	88 & 87	KR480942.1	0.0
	Hyperaspis oregona (cytochrome oxidase subunit 1 (*COI*) gene)	86	KM842010.1	0.0
	Stethorus sp. (cytochrome oxidase subunit 1 (*COI*) gene)	86	KY833723.1	0.0

S. (*Stethorus*) *rani* (CDIK)	Coccinellinae sp. BOLD-2016 (cytochrome oxidase subunit 1 (*COI*) gene)	87	KR480942.1	0.0
	Hyperaspis oregona (cytochrome oxidase subunit 1 (*COI*) gene)	86	KM842010.1	0.0
	Hyperaspis oregona (cytochrome oxidase subunit 1 (*COI*) gene)	86	KM848775.1	0.0
S. (*Stethorus*) sp. 1 (WDPO) *S.* (*Stethorus*) sp. 1 (KWAM)	*Hyperaspis oregona* (cytochrome oxidase subunit 1 (*COI*) gene)	85	KM848775.1	0.0
	Hyperaspis oregona (cytochrome oxidase subunit 1 (*COI*) gene)	85	KM842010.1	0.0
S. (*Stethorus*) sp. 2 (TTRMU)	*Henosepilachna vigintioctopunctata* (cytochrome c oxidase (*COI*) gene)	85	KU234200.1	0.0
	Henosepilachna vigintioctopunctata (mitochondrial *COI* gene for cytochrome oxidase subunit I)	85	AB002180.1	0.0

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	Henosepilachna vigintioctopunctata (cytochrome c oxidase subunit I (*COI*) gene)	84	KJ559395.1	0.0
Stethorus keralicus (VNAR) *Stethorus keralicus* (KPDVDAR) *Stethorus keralicus* (KTRVKAR)	*Henosepilachna vigintioctopunctata* (cytochrome c oxidase (*COI*) gene)	84	KU234200.1	0.0
	Henosepilachna vigintioctopunctata (mitochondrial *COI* gene for cytochrome oxidase subunit I)	84	AB002180.1	0.0
	Henosepilachna vigintioctopunctata (cytochrome c oxidase subunit I (*COI*) gene)	84	KJ559395.1	0.0

Fig. 45. Barcode gap among species of Stethorini

	51	52	54	57	60	61	63	69	70	72	75	78	83	85	88	91	94	97	100	106	107	109	112	115	116	118	127	128	130	133	136	137	139	140	142	145
Parastethorus indira	C	C	T	C	C	C	T	T	T	A	A	A	A	A	A	A	C	T	A	T	T	A	T	T	T	A	G	A	T	T	A	A	C	C	T	T
Parastethorus indira	C	C	T	C	C	C	T	T	T	A	A	A	A	A	A	A	C	T	A	T	T	A	T	T	T	A	G	A	T	T	A	A	C	C	T	T
Parastethorus indira	C	C	T	C	C	C	T	T	T	A	A	A	A	A	A	A	C	T	A	T	T	A	T	T	T	A	G	A	T	T	A	A	C	C	T	T
S.(A.) forficatus	T	T	A	T	T	A	T	T	C	A	G	A	A	G	A	A	T	C	A	A	C	T	T	A	T	A	A	A	T	A	A	A	T	T	A	T
S. (A.) forficatus	T	T	A	T	T	A	T	T	C	A	G	A	A	G	A	A	T	C	A	A	C	T	T	A	T	A	A	A	T	A	A	A	T	T	A	T
S. (A.)forficatus	T	T	A	T	T	A	T	T	C	A	G	A	A	G	A	A	T	C	A	A	C	T	T	A	T	A	A	A	T	A	A	A	T	T	A	T
S. (A.) forficatus	T	T	A	T	T	A	T	T	C	A	G	A	A	G	A	A	T	C	A	A	C	T	T	A	T	A	A	A	T	A	A	A	T	T	A	T
S. (A.) pauperculus	A	T	A	T	C	A	T	T	T	A	A	T	A	A	T	A	T	C	A	G	T	A	T	T	T	A	C	A	T	T	T	A	T	T	A	T
S. (A.) pauperculus	A	T	A	T	C	A	T	T	T	A	A	T	A	A	T	A	T	T	A	A	T	A	T	T	T	A	C	A	T	T	T	A	T	T	A	T
S. (A.) tetranychi	T	T	A	T	T	A	A	G	C	T	A	T	A	A	A	A	T	T	A	T	C	T	T	T	T	A	T	T	T	A	T	T	A	T	A	T
S.(A.) sp.1	T	C	A	C	T	A	T	C	C	A	A	A	A	A	C	A	T	A	A	A	C	A	T	C	C	A	A	A	C	A	A	A	T	C	G	C
S. (A.) sp.1	T	C	A	C	T	A	T	T	C	A	A	A	A	A	C	A	T	A	A	G	C	A	T	C	C	A	A	A	C	A	A	A	T	C	G	C
S. (S.) rani	T	C	A	T	T	C	C	T	T	A	A	T	A	A	A	A	A	T	A	T	T	A	T	T	C	T	A	A	T	T	A	T	T	T	A	T
S. (S.)rani	T	C	A	T	T	C	C	T	T	A	A	T	A	A	A	A	A	T	A	T	T	A	T	T	C	T	A	A	T	T	A	T	T	T	A	T
S. (S.) rani	T	C	A	T	T	C	C	T	T	A	A	A	A	A	A	A	A	T	A	T	T	A	T	T	C	T	A	A	C	T	A	T	T	T	A	T
S. (S.) sp. 1	T	T	A	T	T	A	T	T	C	A	G	T	A	A	A	A	A	A	G	T	T	A	C	G	C	T	A	A	A	T	A	T	T	T	A	T
S. (S.) sp. 1	T	T	A	T	T	A	T	T	C	A	G	T	A	A	A	A	A	A	G	T	T	A	C	G	C	T	A	A	A	T	A	T	T	T	A	T
S. (S.) sp. 2	C	T	A	T	T	T	A	A	T	A	G	A	A	A	G	C	A	T	A	T	T	A	T	T	T	A	G	A	C	A	A	T	A	T	A	T
Stethoruskeralicus	C	T	A	T	T	T	A	A	T	A	G	A	T	A	G	C	A	T	G	T	T	A	T	T	T	A	G	A	C	A	A	T	A	T	A	T
Stethorus keralicus	C	T	A	T	T	T	A	A	T	A	G	A	T	A	G	C	A	T	A	T	T	A	T	T	T	A	G	A	C	G	A	T	A	T	A	T
Stethorus keralicus	C	T	A	T	T	T	A	A	T	A	G	A	T	A	G	C	A	T	A	T	T	A	T	T	T	A	G	A	C	G	A	T	A	T	A	T

	148	151	154	163	166	169	172	175	178	179	181	184	187	190	193	202	205	211	217	220	226	229	232	235	238	241	244	245	247	250	253	254	265	268	271	280
Parastethorus indira	A	T	C	T	T	A	C	A	T	G	A	T	C	T	T	T	C	T	T	T	T	C	A	T	G	C	A	T	A	A	T	T	A	C	C	T
Parastethorus indira	A	T	C	T	T	A	C	A	T	G	A	T	C	T	T	T	C	T	T	T	T	C	A	T	G	C	A	T	A	A	T	T	A	C	C	T
Parastethorus indira	A	T	C	T	T	A	C	A	T	G	A	T	C	T	T	T	C	T	T	T	T	C	A	T	G	C	A	T	A	A	T	T	A	C	C	T
S.(A.) forficatus	A	T	T	C	T	A	C	C	A	G	T	T	T	T	C	T	T	A	T	T	T	G	A	T	A	T	A	T	G	C	T	T	G	T	T	T
S. (A.) forficatus	A	T	T	C	T	A	C	C	A	G	T	T	T	T	C	T	T	A	T	T	T	G	A	T	A	T	A	T	G	C	T	T	G	T	T	T
S. (A.)forficatus	A	T	T	C	T	A	C	C	A	G	T	T	T	T	C	T	T	A	T	T	T	G	A	T	A	T	A	T	G	C	T	T	G	T	T	T
S. (A.) forficatus	A	T	T	C	T	A	C	C	A	G	T	T	T	T	C	T	T	A	T	T	T	G	A	T	A	T	A	T	G	C	T	T	G	T	T	T
S. (A.) pauperculus	G	T	C	C	C	A	T	G	A	G	T	T	A	T	T	C	T	T	A	T	T	C	A	T	A	T	A	C	T	C	T	T	A	T	T	A
S. (A.) pauperculus	A	T	C	C	T	A	T	A	A	G	T	T	A	T	T	C	T	T	A	T	T	C	A	T	A	T	A	C	T	C	T	T	G	T	T	A
S. (A.) tetranychi	G	T	C	T	T	A	T	A	A	G	A	T	T	C	T	T	T	T	T	C	T	A	A	T	A	C	G	C	T	G	T	T	G	C	A	T
S.(A.) sp.1	G	T	T	C	T	G	T	G	T	G	T	T	A	T	C	T	T	A	A	T	T	A	A	T	A	T	A	T	A	G	T	T	G	T	A	T
S. (A.) sp.1	A	T	T	T	T	G	T	G	T	G	C	T	T	T	C	T	T	A	A	T	T	A	A	T	A	T	A	T	A	G	T	T	A	T	A	T
S. (S.) rani	A	T	T	C	T	T	T	T	A	G	T	T	T	C	C	T	T	C	A	T	C	A	G	T	A	C	A	T	A	G	T	T	A	T	C	T
S. (S.)rani	A	T	T	C	T	T	T	T	A	G	T	T	T	C	C	T	T	C	A	T	C	A	G	T	A	C	A	T	A	G	T	T	A	T	C	T
S. (S.) rani	A	T	T	C	T	T	T	T	A	G	T	T	T	C	C	T	T	C	A	T	C	A	G	T	A	C	A	T	A	G	T	T	A	T	C	T
S. (S.) sp. 1	T	C	T	T	T	G	T	T	A	G	C	T	T	T	C	T	C	A	A	T	T	T	A	T	A	T	G	T	A	A	C	T	A	T	A	A
S. (S.) sp. 1	T	C	T	T	T	G	T	T	A	G	C	T	T	T	C	T	C	A	A	T	T	T	A	T	A	T	G	T	A	A	C	T	A	T	A	A
S. (S.) sp. 2	G	T	T	C	T	A	T	A	T	T	A	C	T	C	T	T	T	A	A	T	C	G	A	C	A	T	G	C	T	G	T	C	G	G	T	T
Stethoruskeralicus	G	T	T	C	T	A	T	A	T	T	A	C	T	C	T	T	T	A	A	T	C	G	G	C	A	T	A	C	T	G	T	C	G	G	T	T
Stethorus keralicus	G	T	T	C	T	A	T	A	T	T	A	C	T	C	T	T	T	A	A	T	C	G	G	C	A	T	G	C	T	G	T	C	G	G	T	T
Stethorus keralicus	G	T	T	C	T	A	T	A	T	T	A	C	T	C	T	T	T	A	A	T	C	G	G	C	A	T	A	C	T	G	T	C	G	G	T	T

	283	286	289	290	292	298	299	301	310	311	313	314	316	319	322	325	326	328	330	331	332	334	335	337	338	339	340	341	344	350	352	355	361	364	367	370
Parastethorus indira	C	T	G	C	T	C	A	G	G	T	A	T	A	T	T	T	T	A	C	T	T	G	C	T	C	T	C	T	G	G	T	A	C	G	T	C
Parastethorus indira	C	T	G	C	T	C	A	G	G	T	A	T	A	T	T	T	T	A	C	T	T	G	C	T	C	T	C	T	G	G	T	A	C	G	T	C
Parastethorus indira	C	T	A	C	T	C	A	A	G	T	A	T	A	T	T	T	T	A	C	T	T	G	C	T	C	T	C	T	G	G	T	A	C	G	T	C
S.(A.) forficatus	C	A	T	T	A	T	A	A	A	T	A	T	A	T	T	T	T	A	C	T	T	A	T	A	A	T	T	C	G	A	A	A	A	A	A	A
S. (A.) forficatus	C	A	T	T	A	T	A	A	A	T	A	T	A	T	T	T	T	A	C	T	T	A	T	A	A	T	T	C	G	A	A	A	A	A	A	A
S. (A.)forficatus	C	A	T	T	A	T	A	A	A	T	A	T	G	T	T	T	T	A	C	T	T	A	T	A	A	T	T	C	G	A	A	A	A	A	A	A
S. (A.) forficatus	C	A	T	T	A	T	A	A	A	T	A	T	A	T	T	T	T	A	C	T	T	A	T	A	A	T	T	C	G	A	A	A	A	A	A	A
S. (A.) pauperculus	C	T	C	T	A	C	A	A	A	T	A	C	C	T	G	T	T	A	C	T	T	A	C	A	A	T	T	T	G	A	A	A	A	A	A	G
S. (A.) pauperculus	C	T	C	T	A	C	A	A	A	T	A	C	C	T	A	T	C	A	C	T	T	A	C	A	A	T	T	T	G	A	G	A	A	G	A	G
S. (A.) tetranychi	C	T	T	T	A	C	A	A	A	C	T	T	A	A	T	T	T	A	C	T	T	A	C	A	A	T	T	T	G	A	A	A	A	G	T	G
S.(A.) sp.1	T	T	C	T	A	T	A	A	A	C	T	T	A	T	T	C	T	A	C	T	C	A	C	A	A	T	T	T	G	A	A	A	A	G	C	G
S. (A.) sp.1	T	T	C	T	A	T	A	A	A	C	T	T	A	T	T	C	T	A	C	T	C	A	C	A	A	T	T	T	G	A	A	A	A	G	C	A
S. (S.) rani	C	T	T	C	A	C	A	A	A	C	T	C	C	T	T	T	T	A	C	T	C	T	C	T	A	T	T	T	G	A	A	A	A	A	T	A
S. (S.)rani	C	T	T	C	A	C	A	A	A	C	T	C	C	T	T	T	T	A	C	T	C	T	C	T	A	T	T	T	G	A	A	A	A	A	T	A
S. (S.) rani	C	T	T	C	A	C	A	A	A	C	T	C	C	T	T	T	T	A	C	T	C	T	C	T	A	T	T	T	G	A	A	A	A	A	T	A
S. (S.) sp. 1	C	T	A	C	T	T	A	A	G	C	T	T	A	T	C	C	C	G	C	T	C	T	C	A	A	T	C	T	G	A	G	G	A	A	T	G
S. (S.) sp. 1	C	T	A	C	T	T	A	A	G	C	T	T	A	T	C	C	C	G	C	T	C	T	C	A	A	T	C	T	G	A	G	G	A	A	T	G
S. (S.) sp. 2	C	T	A	T	A	T	T	A	A	C	T	T	A	C	A	C	T	A	C	C	C	A	C	A	C	A	A	C	A	A	A	A	A	T	T	A
Stethoruskeralicus	C	T	A	T	A	T	T	A	A	C	T	T	A	C	A	C	T	A	G	C	C	A	C	A	C	A	A	C	A	A	A	A	A	T	T	A
Stethorus keralicus	C	T	A	T	A	T	T	A	A	C	T	T	A	C	A	C	T	A	G	C	C	A	C	A	C	A	A	C	A	A	G	A	A	T	T	A
Stethorus keralicus	C	T	A	T	A	T	T	A	A	C	T	T	A	C	A	C	T	A	G	C	C	A	C	A	C	A	A	C	A	A	G	A	A	T	T	A

	373	376	382	383	385	388	391	394	395	400	406	407	409	412	416	418	421	422	424	427	430	434	436	439	445	448	449	451	454	455	460	463	466	469	472	475
Parastethorus indira	T	A	T	G	T	T	C	C	C	T	T	C	A	T	G	A	A	T	A	C	A	T	A	A	T	A	T	A	T	T	T	T	T	T	T	T
Parastethorus indira	T	A	T	G	T	T	C	C	C	T	T	C	A	C	G	A	A	T	A	C	A	T	A	A	T	A	T	A	T	T	T	T	T	T	T	T
Parastethorus indira	T	A	T	G	T	T	C	C	C	T	T	C	A	T	G	A	A	T	A	C	A	T	A	A	T	A	T	A	T	T	T	T	T	T	T	T
S.(A.) forficatus	A	A	A	G	T	C	T	A	T	A	T	T	A	A	G	A	C	T	A	T	T	C	T	A	T	A	C	T	C	T	T	A	C	T	A	T
S. (A.) forficatus	A	A	A	G	T	C	T	A	T	A	T	T	A	A	G	A	C	T	A	T	T	C	T	A	T	A	C	T	C	T	T	A	T	T	A	T
S. (A.)forficatus	A	A	A	G	T	C	T	A	T	A	T	T	A	A	G	A	C	T	A	T	T	C	T	A	T	A	C	T	C	T	T	A	C	T	A	T
S. (A.) forficatus	A	A	A	G	T	C	T	A	T	A	T	T	A	A	G	A	C	T	A	T	T	C	T	A	T	A	C	T	C	T	T	A	C	T	A	T
S. (A.) pauperculus	T	C	A	G	T	C	T	A	T	A	T	T	A	T	G	A	A	T	C	T	A	T	A	A	T	A	T	A	T	T	T	A	C	T	T	T
S. (A.) pauperculus	T	T	A	G	T	C	T	A	T	A	T	T	A	T	G	A	A	T	C	T	A	T	A	A	T	A	T	A	T	T	T	A	C	T	T	T
S. (A.) tetranychi	A	A	T	G	T	T	A	T	T	T	T	T	A	T	G	A	T	T	A	T	A	C	T	A	T	A	C	T	C	T	T	A	T	T	T	T
S.(A.) sp.1	A	T	A	G	T	C	T	C	T	G	T	T	A	T	G	A	A	T	A	A	T	T	A	A	T	A	T	A	T	T	A	G	T	A	T	T
S. (A.) sp.1	A	T	A	G	T	C	T	C	T	A	T	T	A	T	G	G	G	T	A	A	T	T	A	A	T	A	T	A	T	T	A	G	T	A	T	T
S. (S.) rani	T	A	T	G	T	T	T	T	T	T	T	T	A	C	G	G	T	T	A	A	A	T	A	T	T	T	C	T	T	T	T	G	C	A	A	C
S. (S.)rani	T	A	T	G	T	T	T	T	T	T	T	T	A	C	G	G	T	T	A	A	A	T	A	T	T	T	C	T	T	T	T	G	C	A	A	C
S. (S.) rani	T	A	T	G	T	T	T	T	T	T	T	T	A	C	G	G	T	T	A	A	A	T	A	T	T	T	C	T	T	T	T	G	C	A	A	C
S. (S.) sp. 1	C	A	T	G	A	C	T	T	T	T	C	T	G	T	G	A	G	T	A	A	A	C	A	T	C	C	C	T	T	T	T	A	T	T	C	T
S. (S.) sp. 1	C	A	T	G	A	C	T	T	T	T	C	T	G	T	G	A	G	T	A	A	A	C	A	T	C	C	C	T	T	T	T	A	T	T	C	T
S. (S.) sp. 2	A	C	T	A	T	C	G	T	T	T	T	A	T	C	A	A	C	C	A	T	T	T	T	T	T	T	T	A	T	C	G	G	T	T	A	T
Stethoruskeralicus	A	C	T	A	T	C	G	T	T	T	T	A	T	C	A	A	C	C	A	T	T	T	T	T	T	T	T	A	C	C	G	G	T	T	A	T
Stethorus keralicus	A	C	T	A	T	C	G	T	T	T	T	A	T	C	A	A	C	C	A	T	T	T	T	T	T	T	T	A	T	C	G	G	T	T	A	T
Stethorus keralicus	A	C	T	A	T	C	G	T	T	T	T	A	T	C	A	A	C	C	A	T	T	T	T	T	T	T	T	A	T	C	G	G	T	T	A	T

	476	478	481	484	485	487	493	496	499	502	505	508	517	520	521	522	523	526	529	530	531	532	533	534	535	538	541	542	543	544	547	548	550	556	559	562
Parastethorus indira	T	A	A	A	G	A	T	T	A	T	C	T	G	T	A	A	T	A	A	A	C	T	T	T	A	A	A	A	C	T	T	T	A	T	A	T
Parastethorus indira	T	A	A	A	G	A	T	T	A	T	C	T	G	T	A	A	T	A	A	A	C	T	T	T	A	A	A	A	C	T	T	T	A	T	A	T
Parastethorus indira	T	A	A	A	G	A	T	T	A	T	C	T	G	T	A	A	T	A	A	A	C	T	T	T	A	A	A	A	C	T	T	T	A	T	A	T
S.(A.) forficatus	T	A	A	A	G	C	T	T	A	T	C	T	G	T	T	C	A	A	A	T	C	A	T	T	A	T	A	A	C	T	T	T	A	T	A	T
S. (A.) forficatus	T	A	A	A	G	C	T	T	A	T	C	T	A	T	T	C	A	A	A	T	C	A	T	T	A	T	A	A	C	T	T	T	A	T	G	T
S. (A.)forficatus	T	A	A	A	G	C	T	T	A	T	C	T	A	T	T	C	A	A	A	T	C	A	T	T	A	T	A	A	C	T	T	T	A	T	A	T
S. (A.) forficatus	T	A	A	A	G	C	T	T	A	T	C	T	G	T	T	C	A	A	A	T	C	A	T	T	A	T	A	A	C	T	T	T	A	T	A	T
S. (A.) pauperculus	T	A	G	T	G	A	T	T	A	T	C	T	C	A	A	C	T	A	A	A	C	A	C	T	A	T	A	A	C	T	T	C	T	T	A	G
S. (A.) pauperculus	T	A	G	T	G	A	T	T	A	T	C	T	C	A	A	C	T	A	A	A	C	A	C	T	A	T	A	A	C	T	T	C	T	T	A	G
S. (A.) tetranychi	T	G	A	T	G	C	T	T	A	T	T	C	A	T	A	C	T	A	A	A	C	A	T	T	G	C	A	A	C	T	T	T	A	A	A	A
S.(A.) sp.1	T	A	A	T	G	A	C	T	A	C	T	T	C	A	A	C	A	A	A	A	C	C	T	T	A	T	A	A	C	T	T	T	A	A	A	A
S. (A.) sp.1	T	A	G	T	G	A	C	T	A	C	T	T	C	A	A	C	A	A	A	A	C	C	T	T	A	T	A	A	C	T	T	T	A	A	A	A
S. (S.) rani	T	A	G	C	G	A	T	T	T	A	T	T	A	T	A	T	A	A	A	A	C	A	T	T	A	C	A	A	C	T	C	T	A	T	A	A
S. (S.)rani	T	A	G	C	G	A	T	T	T	A	T	T	A	T	A	T	A	A	A	A	C	A	T	T	A	C	A	A	C	T	C	T	A	T	A	A
S. (S.) rani	T	A	G	C	G	A	T	T	T	A	T	T	A	T	A	T	A	A	A	A	C	A	T	T	A	C	A	A	C	T	C	T	A	T	A	A
S. (S.) sp. 1	C	A	A	T	G	T	T	C	T	T	C	C	G	T	G	T	A	A	G	A	C	C	T	T	A	T	G	A	C	T	A	C	A	G	A	A
S. (S.) sp. 1	C	A	A	T	G	T	T	C	T	T	C	C	G	T	G	T	A	A	G	A	C	C	T	T	A	T	G	A	C	T	A	C	A	G	A	A
S. (S.) sp. 2	T	A	A	T	A	C	T	T	A	T	T	T	A	A	G	C	T	A	A	A	C	G	T	G	A	T	G	G	T	G	T	T	A	A	A	A
Stethoruskeralicus	T	A	A	T	A	C	T	T	A	T	T	T	A	A	G	C	T	G	A	A	G	G	T	G	A	T	G	G	T	G	T	T	A	A	A	A
Stethorus keralicus	T	A	A	T	A	C	T	T	A	T	T	T	A	A	G	C	T	G	A	A	G	G	T	G	A	T	G	G	T	G	T	T	A	A	A	A
Stethorus keralicus	T	A	A	T	A	C	T	T	A	T	T	T	A	A	G	C	T	G	A	A	G	G	T	G	A	T	G	G	T	G	T	T	A	A	A	A

	565	566	571	574	577	581	583	584	586	587	589	590	592	595	596	598	601	604	608	610	613	616	619	622	625	626	631	632	633	634	635	636
Parastethorus indira	T	T	T	T	C	T	A	C	A	T	A	C	T	T	C	A	T	A	G	A	A	A	T	T	A	T	T	A	A	C	A	G
Parastethorus indira	T	T	T	T	C	T	A	C	A	T	A	C	T	T	C	A	T	A	G	A	A	A	T	T	A	T	T	A	A	C	A	G
Parastethorus indira	T	T	T	T	C	T	A	C	A	T	A	C	T	T	C	A	T	A	G	A	A	A	T	T	A	T	T	A	A	C	A	G
S.(A.) forficatus	T	T	C	A	A	C	A	T	A	C	T	C	T	T	T	A	A	A	G	G	A	T	T	T	G	C	T	A	A	C	T	G
S. (A.) forficatus	T	T	C	A	A	C	T	T	A	C	T	C	T	T	T	A	A	A	G	G	A	T	T	T	G	C	T	A	A	C	T	G
S. (A.)forficatus	T	T	C	A	A	C	A	T	A	C	T	C	T	T	T	A	A	A	G	G	A	T	T	T	G	C	T	A	A	C	T	G
S. (A.) forficatus	T	T	C	A	A	C	A	T	A	C	T	C	T	T	T	A	A	A	G	G	A	T	T	T	G	C	T	A	A	C	T	G
S. (A.) pauperculus	A	T	T	T	T	T	A	T	A	C	T	T	A	T	T	A	C	T	G	A	G	T	T	T	G	C	T	T	A	C	A	G
S. (A.) pauperculus	A	T	T	T	T	T	A	T	A	C	T	T	A	T	T	A	T	T	G	A	G	T	T	T	A	C	T	T	A	C	A	G
S. (A.) tetranychi	T	T	T	T	A	C	T	T	A	C	T	C	T	T	T	A	T	T	G	T	A	T	C	A	A	C	T	A	A	C	A	G
S.(A.) sp.1	T	T	T	A	T	T	A	C	T	T	A	T	A	T	T	A	T	A	G	T	G	T	T	T	A	C	T	A	A	C	T	G
S. (A.) sp.1	T	T	T	A	T	T	A	C	T	T	A	T	A	T	T	A	T	A	G	T	A	T	T	T	A	C	T	A	A	C	T	G
S. (S.) rani	T	T	T	T	A	T	A	C	T	C	T	C	A	T	C	T	T	T	G	A	A	A	T	T	A	C	G	A	C	A	G	A
S. (S.)rani	T	T	T	T	A	T	A	C	T	C	T	C	A	T	C	T	T	T	G	A	A	A	T	T	A	C	G	A	C	A	G	A
S. (S.) rani	T	T	T	T	A	T	A	C	T	C	T	C	A	T	C	T	G	T	C	A	A	A	T	T	A	C	G	A	C	A	G	A
S. (S.) sp. 1	A	C	T	T	A	T	A	C	A	C	C	T	A	A	C	C	A	G	G	T	A	T	T	T	A	C	A	A	C	A	G	A
S. (S.) sp. 1	A	C	T	T	A	T	A	C	A	C	C	T	A	A	C	C	A	G	G	T	A	T	T	T	A	C	A	A	C	A	G	A
S. (S.) sp. 2	A	T	T	T	A	T	A	C	T	T	A	C	T	T	T	A	T	A	G	A	A	T	C	T	A	C	T	A	A	C	T	G
Stethoruskeralicus	A	T	T	T	A	T	A	C	T	T	A	C	T	T	T	A	T	A	G	A	A	T	C	T	A	C	T	A	A	C	T	G
Stethorus keralicus	A	T	T	T	A	T	A	C	T	T	A	C	T	T	T	A	T	A	G	A	A	T	C	T	A	C	T	A	A	C	T	G
Stethorus keralicus	A	T	T	T	A	T	A	C	T	T	A	C	T	T	T	A	T	A	G	A	A	T	C	T	A	C	T	A	A	C	T	G

Fig. 46. Summation of DNA barcode of species of Stethorini studied

Species	Position of nucleotide in mitochondrial cytochrome *c* oxidase subunit I																					
	51	52	54	57	60	61	63	69	70	75	78	83	85	88	91	94	97	100	106	107	109	112
Parastethorus indira	C	C	T	C	C	C	T	T	T	A	A	A	A	A	A	C	T	A	T	T	A	T
S. (A.)forficatus	T	T	A	T	T	A	T	T	C	G	A	A	G	A	A	T	C	A	A	C	T	T
S. (A.)pauperculus	A	T	A	T	C	A	T	T	T	A	T	A	A	T	A	T	C/T	A	G/A	T	A	T
*S. (A.)*sp. 1	T	C	A	C	T	A	T	C/T	C	A	A	A	A	C	A	T	A	A	G/A	C	A	T
S. (S.) rani	T	C	A	T	T	C	C	T	T	A	A/T	A	A	A	A	A	T	A	T	T	A	T
*S. (S.)*sp.1	T	T	A	T	T	A	T	T	C	G	T	A	A	A	A	A	A	G	T	T	A	C
Stethorus keralicus	C	T	A	T	T	T	A	A	T	G	A	T	A	G	C	A	T	G/A	T	T	A	T

Species	Position of nucleotide in mitochondrial cytochrome *c* oxidase subunit I																					
	115	116	118	127	130	133	136	137	139	140	142	145	148	151	154	163	169	172	175	178	181	184
Parastethorus indira	T	T	A	G	T	T	A	A	C	C	T	T	A	T	C	T	A	C	A	T	A	T
S. (A.)forficatus	A	T	A	A	T	A	A	A	T	T	A	T	A	T	T	C	A	C	C	A	T	T
S. (A.)pauperculus	T	T	A	C	T	A	T	A	T	T	A	T	G/A	T	C	C	A	T	G/A	A	T	T
*S. (A.)*sp. 1	C	C	A	A	C	A	A	A	T	C	G	C	G/A	T	T	C/T	G	T	G	T	C/T	T
S. (S.) rani	T	C	T	A	C/T	T	A	T	T	T	A	T	A	T	T	C	T	T	T	A	T	T
*S. (S.)*sp.1	G	C	T	A	A	T	A	T	T	T	A	T	T	C	T	T	G	T	T	A	C	T
Stethorus keralicus	T	T	A	G	C	G/A	A	T	A	T	A	T	G	T	T	C	A	T	A	T	A	C

Species	Position of nucleotide in mitochondrial cytochrome *c* oxidase subunit I																						
	187	190	193	205	211	217	226	229	232	235	238	241	244	245	247	250	253	254	265	268	271	280	
Parastethorus indira	C	T	T	C	T	T	T	C	A	T	G	C	A	T	A	A	T	T	A	C	C	T	
S. (A.)forficatus	T	T	C	T	A	T	T	G	A	T	A	T	A	T	G	C	T	T	G	T	T	T	
S. (A.)pauperculus	A	T	T	T	T	A	T	C	A	T	A	T	A	C	T	C	T	T	A/G	T	T	A/T	
*S. (A.)*sp. 1	A/T	T	C	T	A	A	T	A	A	T	A	T	A	T	A	G	T	T	G/A	T	A	T	
S. (S.) rani	T	C	C	T	C	A	C	A	G	T	A	C	A	T	A	G	T	T	A	T	C	T	
*S. (S.)*sp.1	T	T	C	C	A	A	T	T	A	T	A	T	G	T	A	A	C	T	A	T	A	A	
Stethorus keralicus	T	C	T	T	A	A	C	G	G	C	A	T	G/A	C	T	G	T	C	G	G	T	T	

Species	Position of nucleotide in mitochondrial cytochrome *c* oxidase subunit I																						
	283	286	289	290	292	298	299	310	311	313	314	316	319	322	325	326	328	330	331	332	334	335	
Parastethorus indira	C	T	G/A	C	T	C	A	G	T	A	T	A	T	T	T	T	A	C	T	T	G	C	
S. (A.)forficatus	C	A	T	T	A	T	A	A	T	A	T	G/A	T	T	T	T	A	C	T	T	A	T	
S. (A.)pauperculus	C	T	C	T	A	C	A	A	T	A	C	C	T	G/A	T	C/T	A	C	T	T	A	C	
*S. (A.)*sp. 1	T	T	C	T	A	T	A	A	C	T	T	A	T	T	C	T	A	C	T	C	A	C	
S. (S.) rani	C	T	T	C	A	C	A	A	C	T	C	C	T	T	T	T	A	C	T	C	T	C	
*S. (S.)*sp.1	C	T	A	C	T	T	A	G	C	T	T	A	T	C	C	C	G	C	T	C	T	C	
Stethorus keralicus	C	T	A	T	A	T	T	A	C	T	T	A	C	A	C	T	A	G	C	C	A	C	

Species	Position of nucleotide in mitochondrial cytochrome *c* oxidase subunit I																					
	337	338	339	340	341	344	350	352	355	361	364	367	370	373	376	382	383	385	388	391	394	395
Parastethorus indira	T	C	T	C	T	G	G	T	A	C	G	T	C	T	A	T	G	T	T	C	C	C
S. (A.)forficatus	A	A	T	T	C	G	A	A	A	A	A	A	A	A	A	A	G	T	C	T	A	T
S. (A.)pauperculus	A	A	T	T	T	G	A	G/A	A	A	G/A	A	G/A	A	C/T	A	G	T	C	T	A	T
*S. (A.)*sp. 1	A	A	T	T	T	G	A	A	A	A	G	C	G/A	A	T	A	G	T	C	T	C	T
S. (S.) rani	T	A	T	T	T	G	A	A	A	A	A	T	A	T	A	T	G	T	T	T	T	T
*S. (S.)*sp.1	A	A	T	C	T	G	A	G	G	A	A	T	G	C	A	T	G	A	C	T	T	T
Stethorus keralicus	A	C	A	A	C	A	A	G/A	A	A	T	T	A	A	C	T	A	T	C	G	T	T

Species	Position of nucleotide in mitochondrial cytochrome *c* oxidase subunit I																					
	400	406	407	409	412	416	418	421	422	424	427	430	434	436	439	445	448	449	451	454	455	460
Parastethorus indira	T	T	C	A	C/T	G	A	A	T	A	C	A	T	A	A	T	A	T	A	T	T	T
S. (A.)forficatus	A	T	T	A	A	G	A	C	T	A	T	T	C	T	A	T	A	C	T	C	T	T
S. (A.)pauperculus	A	T	T	A	T	G	A	A	T	C	T	A	T	A	A	T	A	T	A	T	T	T
*S. (A.)*sp. 1	G/A	T	T	A	T	G	G/A	G/A	T	A	A	T	T	A	A	T	A	T	A	T	T	A
S. (S.) rani	T	T	T	A	C	G	G	T	T	A	A	A	T	A	T	T	T	C	T	T	T	T
*S. (S.)*sp.1	T	C	T	G	T	G	A	G	T	A	A	A	C	A	T	C	C	C	T	T	T	T
Stethorus keralicus	T	T	A	T	C	A	A	C	C	A	T	T	T	T	T	T	T	T	A	C/T	C	G

Species	Position of nucleotide in mitochondrial cytochrome *c* oxidase subunit I																					
	463	466	469	472	475	476	481	484	485	487	493	496	499	502	505	508	517	520	521	522	523	526
Parastethorus indira	T	T	T	T	T	T	A	A	G	A	T	T	A	T	C	T	G	T	A	A	T	A
S. (A.)forficatus	A	C/T	T	A	T	T	A	A	G	C	T	T	A	T	C	T	G/A	T	T	C	A	A
S. (A.)pauperculus	A	C	T	A/T	T	T	G	T	G	A	T	T	A	T	C	T	C	A	A	C	T	A
*S. (A.)*sp. 1	G	T	A	T	T	T	G/A	T	G	A	C	T	A	C	T	T	C	A	A	C	A	A
S. (S.) rani	G	C	A	A	C	T	G	C	G	A	T	T	T	A	T	T	A	T	A	T	A	A
*S. (S.)*sp.1	A	T	T	C	T	C	A	T	G	T	T	C	T	T	C	C	G	T	G	T	A	A
Stethorus keralicus	G	T	T	A	T	T	A	T	A	C	T	T	A	T	T	T	A	A	G	C	T	G

Species	Position of nucleotide in mitochondrial cytochrome *c* oxidase subunit I																					
	529	530	531	532	533	534	538	541	542	543	544	547	548	556	562	565	566	571	574	577	581	584
Parastethorus indira	A	A	C	T	T	T	A	A	A	C	T	T	T	T	T	T	T	T	T	C	T	C
S. (A.)forficatus	A	T	C	A	T	T	T	A	A	C	T	T	T	T	T	T	T	C	A	A	C	T
S. (A.)pauperculus	A	A	C	A	C	T	T	A	A	C	T	T	C/T	T	G	A	T	T	T	T	T	T
*S. (A.)*sp. 1	A	A	C	C	T	T	T	A	A	C	T	T	T	A	A	T	T	T	A	T	T	C
S. (S.) rani	A	A	C	A	T	T	C	A	A	C	T	C	T	T	A	T	T	T	T	A	T	C
*S. (S.)*sp.1	G	A	C	C	T	T	T	G	A	C	T	A	C	G	A	A	C	T	T	A	T	C
Stethorus keralicus	A	A	G	G	T	G	T	G	G	T	G	T	T	A	A	A	T	T	T	A	T	C

Species	Position of nucleotide in mitochondrial cytochrome *c* oxidase subunit I																				
	586	587	589	590	592	595	596	598	601	604	610	613	616	619	625	626	631	633	634	635	636
Parastethorus indira	A	T	A	C	T	T	C	A	T	A	A	A	A	T	A	T	T	A	C	A	G
S. (A.)forficatus	A	C	T	C	T	T	T	A	A	A	G	A	T	T	G	C	T	A	C	T	G
S. (A.)pauperculus	A	C	T	T	A	T	T	A	C/T	T	A	G	T	T	G/A	C	T	A	C	A	G
*S. (A.)*sp. 1	T	T	A	T	A	T	T	A	T	A	T	A	T	T	A	C	T	A	C	T	G
S. (S.) rani	T	C	T	C	A	T	C	T	G/T	T	A	A	A	T	A	C	G	C	A	G	A
*S. (S.)*sp.1	A	C	C	T	A	A	C	C	A	G	T	G/A	T	T	A	C	A	C	A	G	A
Stethorus keralicus	T	T	A	C	T	T	T	A	T	A	A	A	T	C	A	C	T	A	C	T	G

Table 12. Pairwise distances of *COI* sequences of Stethorini collected

	1a	1b	1c	2a	2b	2c	2d	3a	3b	4a	4b	5a	5b	5c	6a	6b	7a	7b	7c
1a																			
1b	0.00																		
1c	0.00	0.01																	
2a	0.19	0.19	0.18																
2b	0.19	0.19	0.19	0.01															
2c	0.19	0.19	0.19	0.00	0.01														
2d	0.19	0.19	0.18	0.00	0.01	0.00													
3a	0.17	0.17	0.17	0.14	0.14	0.14	0.14												
3b	0.16	0.16	0.16	0.14	0.14	0.14	0.14	0.02											
4a	0.18	0.18	0.18	0.15	0.15	0.15	0.15	0.15	0.14										
4b	0.18	0.18	0.17	0.14	0.14	0.14	0.14	0.15	0.15	0.03									
5a	0.18	0.17	0.17	0.18	0.18	0.17	0.18	0.17	0.17	0.17	0.15								
5b	0.18	0.17	0.17	0.18	0.18	0.17	0.18	0.17	0.17	0.17	0.15	0.00							
5c	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.15	0.00	0.00						
6a	0.22	0.22	0.21	0.20	0.21	0.21	0.20	0.21	0.21	0.20	0.18	0.17	0.17	0.17					
6b	0.22	0.22	0.21	0.20	0.21	0.21	0.20	0.21	0.21	0.20	0.18	0.17	0.17	0.17	0.00				
7a	0.24	0.23	0.23	0.20	0.20	0.20	0.20	0.23	0.22	0.20	0.20	0.21	0.21	0.21	0.24	0.24			
7b	0.23	0.23	0.23	0.21	0.21	0.21	0.21	0.22	0.21	0.20	0.20	0.21	0.21	0.21	0.24	0.24	0.01		
7c	0.23	0.23	0.23	0.21	0.21	0.21	0.21	0.23	0.22	0.20	0.20	0.21	0.21	0.21	0.23	0.23	0.01	0.00	

1a- *Parastethorus indira* (TPAMA); **1b-** *P. indira* (TTRCA); **1c-** *P. indira* (TNMCA); **2a-** *Stethorus* (*Allostethorus*) *forficatus* (KMPTV); **2b-** *S.* (*A.*) *forficatus* (KTVPA); **2c-** *S.* (*A.*) *forficatus* (KTAPS); **2d-** *S.* (*A.*) *forficatus* (KABG); **3a-** *S.* (*A.*) *pauperculus* (KARAU); **3b-** *S.* (*A.*) *pauperculus* (KALKY); **4a-** *S.* (*A.*) sp. 1 (TTR); **4b-** *S.* (*A.*) sp. 1 (AMCO); **5a-** *S.* (*Stethorus*) *rani* (KID); **5b-** *S.* (*S.*) *rani* (PPCD); **5c-** *S.* (*S.*) *rani* (KIDK); **6a-** *S.* (*S.*) sp. 1 (WDPO); **6b-** *S.* (*S.*) sp. 1 (KWAM); **7a-** *S. keralicus* (VNAR); **7b** *S. keralicus* (KPDVDAR); **7c-** *S. keralicus* (KTRVKAR)

S. (*S.*) sp. 2 and *S. keralicus*. The bootstrap value was low for the major clades formed. The sequences representing individuals of same species always formed group with high bootstrap value.

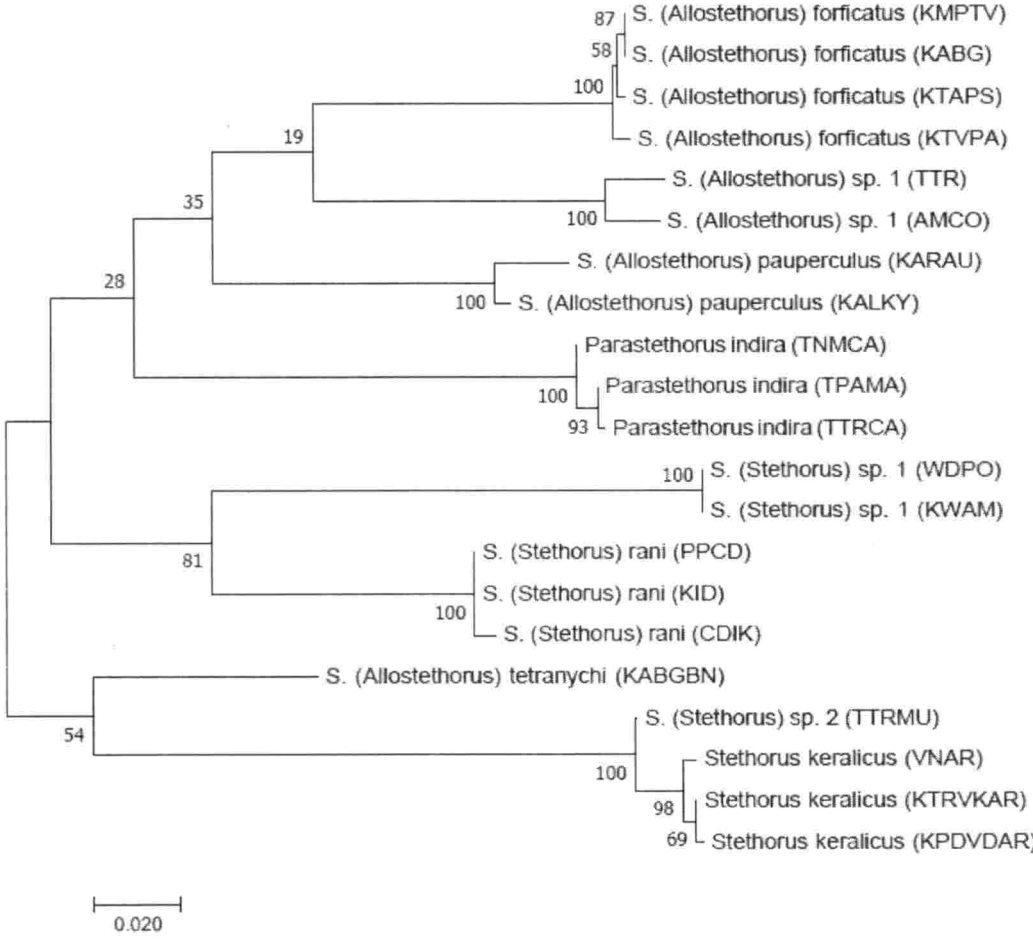

Fig. 47. Phylogeny of species of Stethorini collected during the present study

4. 2. 8. Sequences submitted to NCBI GenBank

Twenty one sequences were submitted to NCBI GenBank and the accession numbers are given (Table 13).

Table 13. NCBI accession numbers for accessions of Stethorini

Species with accession number	NCBI accession number
Parastethorus indira (TPAMA)	MG672475

Parastethorus indira (TTRCA)	MG672476
Parastethorus indira (TNMCA)	MG672477
S. (*Allostethorus*) *forficatus* (KMPTV)	MG672471
S. (*Allostethorus*) *forficatus* (KTVPA)	MG672472
S. (*Allostethorus*) *forficatus* (KTAPS)	MG672473
S. (*Allostethorus*) *forficatus* (KABG)	MG744262
S. (*Allostethorus*) *pauperculus* (KARAU)	MG672468
S. (*Allostethorus*) *pauperculus* (KALKY)	MG672469
S. (*Allostethorus*) *tetranychi* (KABGBN)	MG672474
S. (*Allostethorus*) sp. 1 (TTR)	MG744264
S. (*Allostethorus*) sp. 1 (AMCO)	MG744265
S. (*Stethorus*) *rani* (KID)	MG744266
S. (*Stethorus*) *rani* (PPCD)	MG744267
S. (*Stethorus*) *rani* (CDIK)	MG744268
S. (*Stethorus*) sp. 1 (WDPO)	MG744261
S. (*Stethorus*) sp. 1 (KWAM)	MG744263
S. (*Stethorus*) sp. 2 (TTRMU)	MG672470
Stethorus keralicus (VNAR)	MF592697
Stethorus keralicus (KPDVDAR)	MG672466
Stethorus keralicus (KTRVKAR)	MG672467

4. 2. 9. Barcode for the species of Stethorini

The assembled sequences were submitted to Barcode of Life Data (BOLD) systems along with specimen data, sequence data, trace files and specimen images for generating barcodes. Barcode Index Number was received for one of the accessions, *S. keralicus* (BOLD:ADI4772) and has to be received for the rest of the sequences submitted. The barcode generated for different species of Stethorini is given below.

Parastethorus indira **(TPAMA)**

Parastethorus indira **(TTRCA)**

Parastethorus indira **(TNMCA)**

S. (Allostethorus) forficatus **(KMPTV)**

S. (Allostethorus) forficatus **(KTVPA)**

S. (Allostethorus) forficatus **(KTAPS)**

S. (Allostethorus) forficatus **(KABG)**

S. (Allostethorus) pauperculus **(KARAU)**

S. (Allostethorus) pauperculus **(KALKY)**

S. (Allostethorus) tetranychi **(KABGBN)**

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***Stethorus keralicus* (VNAR)**

***Stethorus keralicus* (KPDVDAR)**

***Stethorus keralicus* (KTRVKAR)**

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Discussion

5. DISCUSSION

The research work on "Systematics of the tribes Scymnini and Stethorini (Coleoptera: Coccinellidae) from south India" was aimed to study the taxonomy of the tribes Scymnini and Stethorini associated with sucking pests in different agricultural ecosystems of south India and to generate DNA barcode for different species of Stethorini collected during the study. Surveys were carried out in 47 geographical locations representing 12 districts of Kerala, four districts of Karnataka and six districts of Tamil Nadu covering the major agricultural ecosystems. The predatory coccinellids collected during the study are discussed for their taxonomic characters, geographical records and prey range.

5. 1. Taxonomy

Sasaji (1971) recognised Scymnini and Stethorini as tribes under the subfamily Scymninae of family Coccinellidae. This system of classification was widely accepted and followed by several authors until recently. However, the new system of classification of the family Coccinellidae based on molecular evidences (Seago *et al.*, 2011), treated Scymnini and Stethorini as parts of the composite tribe Coccidulini under the subfamily Coccinellinae. But the present study treats Scymini and Stethorini as tribes under the subfamily Scymninae.

The tribe Scymnini differs from Stethorini in the morphology of prosternum and metendosternite. In Scymnini, the anterior margin of prosternum is either flat or weakly excavated and metendosternite with narrowly separated anterior tendons. While in Stethorini, anterior margin of prosternum is roundly convex and metendosternite with broadly separated anterior tendons. Prosternal carina may be present or absent in Scymnini, but is always lacking in Stethorini (Sasaji, 1971).

5. 1. 1. Tribe Scymnini

The present study recognised 28 species belonging to six genera *viz.*, *Axinoscymnus*, *Cryptolaemus*, *Horniolus*, *Nephus*, *Sasajiscymnus* and *Scymnus* under the tribe Scymnini. All the six genera under Scymnini reported from India

were included in the study. Fifty seven species of Scymnini have been reported so far from India, whereas 21 species under six genera were reported from south India (Padmalatha and Singh, 1998; Poorani, 2002; 2015a).

The characters studied for the separation of genera under Scymnini include number of antennomeres and tarsomeres, shape of prosternal process, presence of prosternal carina and shape of post coxal line on the first abdominal ventrite. Features of male genitalia were considered for species level identification. The sexes were separated by the dimorphic feature of the sixth abdominal ventrite. The posterior margin of sixth abdominal ventrite is usually notched to some degree in males, whereas narrowly and evenly rounded in females (Poorani, 2015b).

Among the different genera studied, genus *Cryptolaemus* is easily separated from others with anteriorly produced prosternum, which covers mouth parts and also with a short and weak prosternal carina. Presence of inverted Y-shaped carina on prosternal process separates *Horniolus* from other genera. Genus *Axinoscymnus* and *Sasajiscymnus* are closely related with three tarsomeres and prosternum with narrow basisternum and short prosternal process, but can be differentiated by the number of antennomeres, nature of post coxal line and male genitalia. Genus *Nephus* and *Scymnus* can be separated by the number of antennomeres, tarsomeres, prosternal carina and shape of post coxal line on the first abdominal ventrite. (Sasaji, 1971).

5. 1. 1. 1. Genus *Axinoscymnus* H. Kamiya, 1963

Genus *Axinoscymnus* is distributed in Oriental and Palaearctic region (Sasaji, 1971). The present study recognised two species under *Axinoscymnus*, of which one could be identified only upto generic level, as the male specimens were lacking. The one which is identified upto species level was *A. puttarudriahi*, which was first described from India (Kapur and Munshi, 1965). *Axinoscymnus puttarudriahi* is distinguished with a discal large yellowish brown oval marking on each elytron, whereas the elytra of *Axinoscymnus* sp. 1 is black with orange tip.

Axinoscymnus puttarudriahi is the only species of *Axinoscymnus* reported from India so far (Poorani, 2002).

5. 1. 1. 2. Genus *Cryptolaemus* Mulsant, 1853

Cryptolaemus montrouzieri, the only species identified under this genus during the present study, can be easily distinguished with the characteristic setae on parameres. *Cryptolaemus* is indigenous to the Australasian region (Booth and Pope, 1986; Slipinski, 2007) and forty species belonging to six species groups were described so far under this genus (Booth and Pope, 1986; Poorani *et al.*, 2014).

Cryptolaemus montrouzieri is an important predator of mealybugs and had been introduced throughout the world for biological control (Booth and Pope, 1986). It was released in Nilgiri Hills, Tamil Nadu in 1898 to check *Coccus viridis* and other mealybugs on coffee (Mayne, 1953) and documented as the first deliberately introduced natural enemy in India (NBAIR, 2013).

5. 1. 1. 3. Genus *Horniolus* Weise, 1900

Horniolus occurs in Oriental and Palearctic region with 15 species described worldwide (Chen *et al.*, 2016b). The only species of *Horniolus* recognised during the study is *H. sororius*, which was described recently by Poorani (2015a). Najitha (2016) reported *H. sororius* (as *Horniolus* sp.) as a predator of pepper root mealybug from Kerala. Of the four *Horniolus* species reported from Indian subcontinent, only two species were identified from India: *H. nigripes* Miyatake on aphids from Tamil Nadu and *H. sororius* Poorani on coffee mealybugs from Karnataka (Pooani, 2002, 2015a; Omkar and Pervez, 2004).

5. 1. 1. 4. Genus *Nephus* Mulsant 1846

Nephus is a widely distributed genus of Scymnini present in the Nearctic region (Gordon, 1985), Oriental region (Kapur, 1967; Poorani, 2002), Afrotropical region (Walton and Pringle, 2004) and Palaearctic region (Sasaji, 1971).

Three species of *Nephus* recognised during this study include *N. regularis*, *N. tagiapatus* and *Nephus* sp.1, of which *Nephus* sp.1 may probably be a new species. *Nephus regularis* was first described by Sicard in 1929 as *Scymnus* (*Nephus*) *regularis*. Chelliah (1965) included this species in his study on "The male genitalia of a few predaceous coccinellids of south India". Pang and Gordon (1984) redescribed *N. regularis* with illustrations of male genitalia. *Nephus tagiapatus* was first described by Kamiya (1965b) as *Scymnus* (*Nephus*) *tagiapatus* from Ryukyu Islands, Japan. But, Kapur (1967) described this as a new species, *N. roonwali* from Andamans, India. Later, Sasaji (1968) synonymized *N. roonwali* with *N. tagiapatus*.

Of the six species reported so far from Indian subregion, five species are present in India. Of these, *N. lentiformis* (Booth) and *N. regularis* (Sicard) are reported from south India, whereas *N. tagiapatus* (Kamiya) from Andamans and Calcutta (Kapur, 1967; Poorani, 2002).

5. 1. 1. 5. Genus *Sasajiscymnus* Vandenberg, 2004

Genus *Sasajiscymnus* has about 50 known species mainly from East Asia and Africa (Yu *et al.*, 2000). Vandenberg (2004) proposed *Sasajiscymnus* as a replacement name and objective synonym for *Pseudoscymnus* Chapin, 1962.

The current study recognised one species of *Sasajiscymnus*. Of the four species of *Sasajiscymnus* from India, two species *viz.*, *S. dwipakalpa* (Ghorpade) and *S. luteus* (Sicard) were reported from south India.

5. 1. 1. 6. Genus *Scymnus* Kugelann, 1794

Scymnus is a cosmopolitan genus with more than 800 species throughout the world (Chen *et al.*, 2013). Even though it is a large and speciose genus, its small size and lack of distinct external characters put their classification behind other genera of Coccinellidae during early days (Gordon, 1976). Of the eight subgenera of *Scymnus* recognised throughout the world (Chen *et al.*, 2013), only four subgenera are reported from Indian subregion. Twelve species belonging to

three subgenera were reported from south India. (Padmalatha and Singh, 1998; Poorani, 2002; 2015a).

This study recognised 20 species of *Scymnus* representing three subgenera. All the subgenera reported from south India *viz.*, *S.* (*Neopullus)*, *S.* (*Pullus*) and *S.* (*Scymnus*) were studied. Subgenus *Neopullus* can be distinguished from members of other subgenera by the presence of antenna with 10 antennomeres and first abdominal ventrite with complete post coxal line having uniform punctation in the area enclosed by the line. Post coxal line on first abdominal ventrite is complete in the members of subgenus *Pullus*, whereas it is incomplete and recurved upward basally in subgenus *Scymnus* (Sasaji, 1971).

The taxonomic features of two species *viz.*, *Scymnus saciformis* and *Scymnus* sp. 1 recognised during the study distinctly varied from the characters of already described subgenera. These two species vary from other members of the genus by the presence of antenna with 10 antennomeres, trimerous tarsi and prosternal carina which is very strongly divergent posteriorly. These species are not well placed in any subgenera and hence treated separately. The taxonomic status of these species has to be reviewed (J. Poorani, *in litt.*)

5. 1. 1. 6. 1. Subgenus *Scymnus* (*Neopullus*) Sasaji, 1971

Scymnus (*Neopullus*) is distributed in the Palaearctic and Oriental regions and 29 species have been reported so far (Chen *et al.*, 2014). Two species included in the present study are *S.* (*N.*) *hoffmanni* and *S.* (*N.*) sp. 1. The length of penis guide with respect to parameres is an important character in separating the species of *S.* (*Neopullus*).

Of the three species of *S.* (*Neopullus*) reported from India, and *S.* (*N.*) *fuscatus* is the only species so far reported from south India (Poorani, 2002). However, Poorani (2002) mentioned that *S.* (*N.*) *hoffmanni* is a doubtful record for India.

5. 1. 1. 6. 2. Subgenus *Scymnus* (*Pullus*) Mulsant, 1846

Subgenus *Scymnus* (*Pullus*) is distributed worldwide and is the largest subgenus of *Scymnus*, with more than 500 species from the world (Chen *et al.*, 2015a). The species recorded from south India under this genus are eight, of which only four are reported so far from Kerala (Poorani, 2002; Jose, 2003).

Fifteen species were identified during the study, among which only fourteen were studied upto species level, as the male specimen was lacking in one species. Of these, *S.* (*Pullus*) sp. 4, *S.* (*Pullus*) sp. 5, *S.* (*Pullus*) sp. 6, *S.* (*Pullus*) sp. 7 and *S.* (*Pullus*) sp. 9 are probably new species. Chen *et al.* (2015a) classified *S.* (*Pullus*) into five species groups based on the male genitalia. The species identified during the present study, are classified into these species groups.

a. ***Hingstoni*** group in which the penis guide is broad with a prominent dorsal keel. *S.* (*P.*) sp. 9 is classified in this group as it agrees with the characters of this group.
b. ***Subvillosus*** group in which the members have strongly expanded, trumpet-shaped penis capsule. *S.* (*P.*) *coccivora* and *S.* (*P.*) *latemaculatus* belong to this group.
c. ***Sodalis*** group where the penis capsule is normal with inner and outer arm or with indistinct outer arm and apex of penis with a thread-like appendage. Among the species recognised in the present study, *S.* (*P.*) *castaneus*, *S.* (*P.*) *pyrocheilus*, *S.* (*P.*) *utilis*, *S.* (*P.*) sp. 1, *S* (*P.*) sp. 2, *S.* (*P.*) sp. 3, *S.* (*P.*) sp. 4 and *S.* (*P.*) sp. 5 are included in this group.
d. ***Impexus*** group in which the penis capsule is normal with inner and outer arm or with indistinct outer arm and apex of penis simple. *S.* (*P.*) sp. 6, *S.* (*P.*) sp. 7 and *S.* (*P.*) sp. 8 belong to this group.

5. 1. 1. 6. 3. Subgenus *Scymnus* (*Scymnus*) Kugelann, 1794

Subgenus *Scymnus* of *Scymnus* is also distributed worldwide. *S.* (*S.*) *nubilus* is the only species of subgenus *Scymnus* recognised during the present study.

Of the eight species reported from India, *S.* (*S.*) *andrewesi*, *S.* (*S.*) *indicus* and *S.* (*S.*) *nubilus* are reported from south India (Poorani, 2002).

5. 1. 2. Tribe Stethorini Dobzhansky, 1924

Members of Stethorini look similar, which are black without any markings on pronotum and elytra. The two genera recognised under Stethorini include *Parastethorus* and *Stethorus*. *Parastethorus* can be distinguished from *Stethorus* by the presence of incomplete post coxal line in the first abdominal ventrite and relatively stout parameres with short spine like setae on the inner side. The structure of male genitalia is the specific reliable feature for species level identification. This can be correlated with certain external characters like shape of post coxal line on the first abdominal ventrite and posterior margin of sixth abdominal ventrite. In females, ninth sternite is divided into a paired structure and its shape varies in different species. Spermatheca is not usually sclerotised or sometimes lacking. The sixth abdominal ventrite of females are entire (Kapur, 1948).

Stethorini is distributed throughout the world in different climates ranging from tropical rainforests to temperate deciduous forests and plains to colder northern regions (Biddinger *et al.*, 2009). Seven species belonging to two subgenera were reported so far from south India (Poorani, 2002; 2017). The two genera recognised under Stethorini so far, are included in the present study.

5. 1. 2. 1. Genus *Parastethorus* Pang & Mao, 1975

Parastethorus, erected as a subgenus of *Stethorus*, was later raised to generic status (Slipinski, 2007). Two species reported from India, *Stethorus* (*Parastethorus*) *guangxiensis* Pang & Mao and *S.* (*P.*) *indira* (Kapur), that were placed under the genus *Stethorus*, were transferred to *Parastethorus* with the

erection of this new genus (Yu, 1996). Later, Poorani (2002) synonymised *S.* (*P*) *guangxiensis* as a junior synonym of *S.* (*P.*) *indira*. So, only one species of *Parastethorus* is recognised from India, which is included in the study.

5. 1. 2. 2. Genus *Stethorus* Weise, 1885

Stethorus is a worldwide genus, with 94 described species all over the world (Li *et al.*, 2013). Eight species of *Stethorus* are reported from India so far (Poorani, 2002, 2017; Babu, 2012). *Stethorus* is represented by two subgenera *S.* (*Allostethorus*) and *S.* (*Stethorus*), members of which are distinguished by the variation in the features of male genitalia.

Of the nine species of *Stethorus* collected during the present study, four belong to the subgenus *S.* (*Allostethorus*): *S.* (*A.*) *forficatus*, *S.* (*A.*) *pauperculus*, *S.* (*A.*) *tetranychi* and *S.* (*A.*) sp. 1 and four to *S.* (*Stethorus*): *S.* (*S.*) *rani*, *S.* (*S.*) sp. 1, *S.* (*S.*) sp. 2 and *S.* (*S.*) sp. 3. Of these, *S.* (*Allostethorus*) sp.1 and *S.* (*Stethorus*) sp. 1 may probably be new species. Another species, *S. keralicus* do not completely agree with the characters of any of these two subgenera. *Stethorus keralicus* differ from subgenus *Allostethorus* with the parameres distinctly shorter than penis guide and from subgenu *Stethorus* by the presence of short, stout penis. Besides, antenna of *S. keralicus* is composed of 10 antennomeres, whereas in all other members of Stethorini antenna is composed of 11 antennomeres. Hence in the present study, *S. keralicus* is treated separately without accommodating it into any described subgenus. *Stethorus keralicus* differ from all other species in general appearance and can be identified by external appearance from other species studied. Poorani (2017) also treated *S. keralicus* separately without accommodating in any of the two subgenera of *Stethorus* identified so far.

All the species, except *S. gilvifrons* (Mulsant), reported from Indian subregion were studied during the period.

5. 2. Distribution and prey range

5. 2. 1. Distribution and prey range of species of Scymnini

Members of Scymnini are cosmopolitan and were collected from different locations in the study area. Species like *Axinoscymnus puttarudriahi*, *Scymnus* (*Pullus*) *coccivora*, *S.* (*P.*) *latemaculatus*, *Scymnus saciformis* were found to be very common in the study area. This study reports the occurrence of *Axinoscymnus* sp.1 and *S.* (*P.*) *utilis* from India, *Nephus tagiapatus* and *S.* (*N.*) *hoffmanni* from south India as well as that of *N. regularis* and *Scymnus* sp.1 from Kerala for the first time.

This study also revealed that species of Scymnini prey upon mealybugs, aphids, whiteflies and scales. Members of Scymnini are predators of aphids, mealybugs, scales, whiteflies, adelgids, thrips and mites (Hodek and Honek, 2009; Obrycki *et al.*, 2009; Omkar and Pervez, 2004). The prey range of Scymnini at species level extends across different families within Sternorrhyncha (Omkar and Pervez, 2004; NBAIR, 2013).

Axinoscymnus puttarudriahi was found to be predaceous on whitefly species, *Aleurodicus dispersus* and *Bemisia tabaci*. This was found commonly associated with highly populated whitefly colonies. Species of *Axinoscymnus* are known as specific whitefly feeders and is very common in south Indian states (Kerala, Karnataka, Tamil Nadu and Lakshadweep Islands) (NBAIR, 2013).

Cryptolaemus montrouzieri, collected from all the three states of south India, was found to be associated with *Planococcus* sp., *Ferrisia virgata* and *Paracoccus marginatus* on different crops. It is the common predator of mealybugs and scales of several horticultural and plantation crops and ornamentals of south India (NBAIR, 2013). Even though *C. montrouzieri* was released in coffee plantations in Wayanad to check coffee mealybugs in 1976 (Chacko *et al.*, 1978) its presence in plain lands of Kerala was not reported so far. However, this study recorded the natural occurrence of *C. montrouzieri* in association with *Planococcus* sp. on a weed host, *Macaranga peltata* in one of the locations at Thrissur district.

Horniolus sororius was found in association with pepper root mealybug, *Formicococcus polysperes* in Wayanad. Najitha (2016) reported this species (as *Horniolus* sp.) as a predator of pepper root mealybug from Kerala. *Horniolus sororius* was earlier recorded as predators of spiralling whitefly, *A. dispersus* (Ramani *et al.*, 2002) and coffee mealybugs (Poorani, 2015). Species of *Horniolus* mostly prey on mealybugs, such as *Planococcus lilacinus* Cockerell and *Dysmicoccus brevipes* (Cockerell) infesting coffee, tea and pineapple and play an important role in the biological control of this pest (Irulandi *et al.*, 2001; He *et al.*, 2013, Poorani, 2015a).

The three species of *Nephus* identified during the study were found feeding on different species of mealybugs *viz.*, *Coccidohystrix insolita*, *Ferrisia virgata*, *Phenacoccus madeirensis*, *Saccharicoccus sacchari* and *Planococcus citri*. *Nephus regularis* is reported from different parts of India associated with aphids, mealybugs, scales and whiteflies (Omkar and Pervez, 2004; NBAIR, 2013). The present study revealed its occurrence in Kerala, Karnataka and Tamil Nadu.

Sasajiscymnus sp. 1 was collected in association with banana scale, *Aspidiotus destructor*. Species of *Sasajiscymnus* is reported as predators of scales, aphids and adelgids (Yu *et al.*, 2000; Omkar and Pervez, 2004)

Genus *Scymnus* is cosmopolitan and is the most common genus of Scymnini associated with different species of mealybugs and aphids. Among the members of *Scymnus*, *S.* (*P.*) *castaneus*, *S.* (*P.*) *latemaculatus*, *S.* (*P.*) *pyrocheilus*, *S.* (*P.*) sp.1, *S.* (*P.*) sp.2, *S.* (*P.*) sp.3, *S.* (*P.*) sp.4, *S.* (*P.*) sp.5, *S.* (*S.*) *nubilus* and *S.* (*N.*) sp.1 were collected in association with aphids while, *S.* (*P.*) *coccivora*, *S.* (*P.*) sp.6, *S.* (*P.*) sp. 7, *S.* (*P.*) sp.8, *S.* (*P.*) sp. 9, *S.* (*P.*) sp. 10 and *S. saciformis* and *S.* sp. 1 were collected in association with mealybugs. The most common species of *Scymnus* associated with mealybugs were *S.* (*P.*) *coccivora* and *S. saciformis*, whereas *S.* (*P.*) *latemaculatus* was very common with aphids. *Scymnus* (*Pullus*) *pyrocheilus* is another species often found with aphids in Kerala. In this study, *S.* (*P.*) *coccivora* and *S. saciformis* recorded the widest prey range which include six species of mealybugs each. *Saccharicoccus sacchari* (Cockerell) and *Toxoptera*

odinae (van der Goot) were reported as new prey records of *Nephus tagiapatus* and *S. (P.) pyrocheilus* respectively.

5. 2. 2. Distribution and prey range of species of Stethorini

Species of Stethorini were recorded from almost all the locations of study area and found to be associated only with mites. *Stethorus (Allostethorus) pauperculus* was found to be the most commonly distributed species associated with mites on different crops. Six species of Stethorini *viz.*, *Parastethorus indira*, S. *(A.) forficatus*, *S. (A.) tetranychi*, *S. (A.)* sp. 1, *S. (Stethorus) rani* and *S. (S.)* sp. 1 are recorded for the first time from Kerala. *Stethorus (Stethorus)* rani and *S. (S.)* sp. 1 was recorded from the high range zone, Wayanad and Ambalavayal respectively. Phylogenetic analysis also showed that these two are closely related species. Kapur (1948) mentioned *S. (S.) rani* as a Himalayan species when he first described the species and designated Kumaon Hills, India as its type locality.

Stethorini is the only mite specialist predator under the family Coccinellidae (Biddinger *et al.*, 2009). Some species in the taxa are prey specific to generic level (Hagen *et al.*, 1999). During this study, *Parastethorus indira* was found to be associated with *Eutetranychus orientalis* and *S. keralicus* with *Raoiella indica*. Carrillo *et al.* (2012) also recorded the specificity of *Stethorus keralicus* to the mites of genus *Raoiella*. In Kerala, whenever there was mite infestation in arecanut, *S. keralicus* was found in association. Daniel (1981) considered *S. keralicus* as the most important predator of *R. indica* in Kerala. *Stethorus keralicus* is a voracious predator of all stages of *R. indica* and found throughout the year (Carrillo *et al.* 2012).

Stethorus (Allostethorus) pauperculus recorded wider host range which include *Oligonychus indicus* (Hirst), *Tetranychus macfarlanei* Baker and Pritchard, and *Tetranychus truncatus* Ehara as their prey. New prey records for Stethorini includes *Tetranychus okinawanus* and *T. truncatus* for *Stethorus forficatus*; *T. macfarlanei* for *S. pauperculus* and *Eutetranychus orientalis* for *P. indira*.

5.3. Barcoding of Stethorini

Nine species of *Stethorus viz.*, *S. keralicus*, *S.* (*A.*) *forficatus*, *S.* (*A.*) *pauperculus*, *S.* (*A.*) *tetranychi* and *S.* (*A.*) sp. 1, *S.* (*S.*) *rani*, *S.* (*S.*) sp. 1, *S.* (*S.*) sp. 2 and one species of *Parastethorus*, *P.indira* were used for barcoding studies.

The concentration of DNA isolated from the members of Stethorini, was relatively less (3.78-16.65 ng/µl), but quite enough for the amplification of desired region and further sequencing. The contigs formed by assembling forward and reverse sequences were of 657-704 bp length. The universal primers, LCO 1490 and HCO 2198 amplified a 710bp region of mitochondrial cytochrome oxidase subunit I gene (Folmer *et al.*, 1994).

Per cent homology of the sequences developed during the study with the database of GenBank showed that all the sequences except that of *P. indira* resulted in <90 per cent homology with the available sequences. All the sequences showed maximum similarity with species from other genera, but from same family, Coccinellidae. This is due to the unavailability of sequences of *Stethorus* in the NCBI database. This indicates that the *COI* sequences of the species of Stethorini studied may not have been submitted earlier in the database.

Out of the three main clades formed by phylogenetic analysis, one was represented by three species of subgenus *Allostethorus*, second clade by two species of subgenus *Stethorus*. The third clade was represented by one species each of the two subgenera along with *Stethorus keralicus*. *Parastethorus indira* appeared as outgroup to subgenus *Allostethorus*. The low boot strap value in the presented tree was low and this indicates that the analysis using mitochondrial cytochrome *c* oxidase subunit I alone is not sufficient to study the phylogenetic relationships between these species.

Summary

6. SUMMARY

Considering the economic importance of family Coccinellidae as predators of agriculturally important pests, the present investigation on "Systematics of the tribes Scymnini and Stethorini (Coleoptera: Coccinellidae) from south India" was undertaken in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 2015-17. The objectives of the investigation were to study the taxonomy of the tribes Scymnini and Stethorini associated with sucking pests in different agricultural ecosystems of south India, to prepare a key for the identification of the species of Scymnini and Stethorini and to generate DNA barcode for different species of Stethorini collected during the study.

An extensive survey was carried out in 22 districts of south Indian states of Kerala, Karnataka and Tamil Nadu covering 47 locations and 64 crops under different agricultural ecosystems *viz.*, fruits, vegetables, plantation crops and ornamentals. The collected specimens were preserved as per standard procedures and used for taxonomic studies and barcoding. All the taxa treated are described and illustrated. Keys have been provided for the tribes, genera and species. Prey range and distribution of species were also documented. Numbers are given for all the putative new species.

The salient finding of the study are furnished below.

- A total of 1540 specimens were studied under the tribes Scymnini and Stethorini.
- The study recognised 28 species under Scymnini belonging to six genera *viz.*, *Axinoscymnus*, *Cryptolaemus*, *Horniolus*, *Nephus*, *Sasajiscymnus* and *Scymnus*. Genus *Scymnus* was represented by 20 species of which 18 species are described under three subgenera *viz.*, *Scymnus* (*Neopullus*), *Scymnus* (*Pullus*) and *Scymnus* (*Scymnus*). Two species were treated separately in this study, as these varied distinctly from the described subgenera. In the study, genus *Nephus* was represented by three species, genus *Axinoscymnus* with two species and genera *Cryptolaemus*, *Horniolus* and *Sasajiscymnus* with one species each.

- Six species, one of genus *Nephus* and five of genus *Scymnus* (*Pullus*) are putative new species. These species have not been given names, as these need to be further investigated after getting information on the primary types of the known species. Two species are recorded for the first time in India and two from south India and two are new records for Kerala.
- The tribe Stethorini was represented by 10 species in two genera *viz*., *Stethorus* and *Parastethorus*. The genus *Parastethorus* was represented by only one species. Two subgenera recognised under the genus *Stethorus* were *Stethorus* (*Allostethorus*) and *Stethorus* (*Stethorus*) represented by four species each. *Stethorus keralicus*, one of the most common species, was treated separately in this study, as its characters were not in agreement with the described subgenera.
- One species each under *Stethorus* (*Allostethorus*) and *Stethorus* (*Stethorus*) are putative new species. Further investigations are needed for the naming of these species. Six species of Stethorini were recorded for the first time in Kerala.
- Twenty one species of prey in four families *viz*., Aphididae, Pseudococcidae, Aleurodidae and Diaspididae were recorded in association with the tribe Scymnini. Two new prey records for Scymnini in the study include *Toxoptera odinae* for *Scymnus pyrocheilus* and *Saccharicoccus sacchari* for *Nephus tagiapatus*. Among Scymnini, *Scymnus coccivora* and *S. saciformis* were found to be widely distributed in the study area and also recorded wider host range with six species as prey, while genus *Axinoscymnus*, though widely distributed, was specific predator of whiteflies.
- Seven species of five genera were identified as prey for species of Stethorini. Among Stethorini, *Stethorus pauperculus* was found to be the predominant species with wider host range, while *S. keralicus* was specific to *Raoiella indica*. New prey records for Stethorini in the study included, *Tetranychus okinawanus* and *T. truncatus* for *S. forficatus*; *T. macfarlanei* for *S. pauperculus* and *Eutetranychus orientalis* for *Parastethorus indira*.
- Species distribution map was prepared for the species of Scymnini and Stethorini using QuantumGIS software.

- Twenty one accessions belonging to nine species of Stethorini were used for barcoding studies.
- DNA was isolated using Qiagen DNeasy kit and the *COI* locus was amplified and sequenced. The sequences were aligned with Clustal W of MEGA 7 and characteristic barcode gaps were identified. Pairwise distances between the sequences were analysed which showed that intraspecific divergence ranged between 0.00 to 0.03, while the interspecific distance ranged between 0.14 to 0.24. A phylogenetic tree was constructed with 21 sequences in MEGA 7 using the maximum likelihood method. The low boot strap value indicates that *COI* alone is not sufficient to give the phylogenetic relationships of these species. The sequences were submitted to GenBank (NCBI) and to BOLD for the generation of species specific barcodes.

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Appendices

APPENDIX I

GPS Coordinates of locations surveyed

State/District	Location	Latitude (^{0}N)	Longitude (^{0}E)
KERALA			
Kasaragod	Padannakkad	12.256605	75.116907
Kannur	Panniyur	12.080896	75.395983
Wayanad	Banasura Sagar	11.670000	75.957778
	Kariampady	11.682437	76.129096
	Pulpally	11.792278	76.166287
	Ambalavayal	11.616500	76.214015
Kozhikode	Mukkam	11.321249	75.996346
Malappuram	Tavanur	10.852594	75.986052
Palakkad	Vadakarapathy	10.782453	76.854799
	Vadakkenchery	10.592800	76.482335
	Vandazhy	10.572094	76.525980
Thrissur	Avinissery	10.470612	76.231979
	Chalakkudy	10.313067	76.341795
	Chazhur	10.435060	76.140693
	Chembukkavu	10.530496	76.220391
	Cherpu	10.432370	76.204455
	Chirakkakkode	10.562641	76.292084
	Elavally	10.569954	76.088501
	Kodannur	10.466463	76.184198
	Kottepadam	10.543906	76.279546
	Marakkal	10.537330	76.320060
	Mannuthy	10.528479	76.268187
	Moorkkinikkara	10.512510	76.279771

	Olarikkara	10.519263	76.185279
	Ollur	10.480662	76.242119
	Parakkad	10.716672	76.357940
	Pattikkad	10.5496	76.3352
	Payyanam	10.518235	76.328545
	Vellanikkara	10.548015	76.283029
Ernakulam	Perumbavoor	10.131939	76.482185
	Vazhakulam	9.943446	76.638463
Idukki	Pampadumpara	9.798692	77.161611
Kottayam	Kumarakom	9.627375	76.431592
Alappuzha	Kayamkulam	9.176330	76.517372
Thiruvananthapuram	Sreekaryam	8.545276	76.914865
	Vellayani	8.429437	76.988012
KARNATAKA			
Raichur	UAS campus	17.898374	77.527699
Dharwad	UAS campus	15.488925	74.981276
Shivamogga	UAHS campus	13.974085	75.579451
Bengaluru	UAS campus	13.077659	77.580466
TAMIL NADU			
Thiruchirappalli	HC & RI for women campus	10.7531	78.5999
Tiruppur	Madathukulam	10.559584	77.3665461
Coimbatore	TNAU campus	11.012326	76.935453
Dindigul	HRS, Kodaikanal	10.2248	77.470407
Madurai	AC & RI campus	9.969856	78.203998
	T.Kallupatti	9.721362	77.855309
Theni	HC & RI , Periyakulam	10.128267	77.599809

APPENDIX II

Details on the locations and associated taxa of Stethorini used for DNA isolation

Accession number	Locations	Crop/ prey
TPAMA	Tamil Nadu/ Madathukulam	Castor/ *Eutetranychus orientalis*
TTRCA	Tamil Nadu/ Madathukulam	Castor/ *Eutetranychus orientalis*
TNMCA	Tamil Nadu/ Madathukulam	Castor/ *Eutetranychus orientalis*
KMPTV	Kerala/ Tavanur	Cosmos/ *Tetranychus* sp.
KTVPA	Kerala/ Vellanikkara	Papaya/ *Tetranychus* sp.
KTAPS	Kerala/ Avinissery	*Butea monosperma*/ *Tetranychus* sp.
KABG	Karnataka / Bengaluru	Bauhinia/ prey not known
KARAU	Karnataka / Raichur	Maize/ *Oligonychus indicus*
KALKY	Kerala/ Kayamkulam	Banana/ prey not known
RABH	Karnataka/ Raichur	Bhinidi/ *Tetranychus* sp.
KABGBN	Karnataka / Bengaluru	Bauhinia/ prey not known
TTR	Tamil Nadu/ Tiruchirappalli	Coconut/ *Tetranychus* sp.
AMCO	Kerala/ Ambalavayal	*Tetranychus* sp.
KID	Kerala/ Pampadumpara	Cardamom/ *Tetranychus* sp.
PPCD	Kerala/ Pampadumpara	Cardamom/ *Tetranychus* sp.
CDIK	Kerala/ Pampadumpara	Cardamom/ *Tetranychus* sp.
WDPO	Kerala/ Ambalavayal	Pomegranate/ *Brevipalpus phoenicis*
KWAM	Kerala/ Ambalavayal	Pomegranate/ *Brevipalpus phoenicis*
TTRMU	Tamil Nadu/ Tiruchirappalli	*Desmodium* sp./ *Tetranychus* sp.
VNAR	Kerala/ Vandazhy	Arecanut/ *Raoiella indica*
KPDVDAR	Kerala/ Vadakkenchery	Arecanut/ *Raoiella indica*
KTRVKAR	Kerala/ Vellanikkara	Arecanut/ *Raoiella indica*

APPENDIX III

CHECK LIST FOR INDIAN SCYMNINI AND STETHORINI

Tribe Scymnini

Genus / Species

***Axinoscymnus* H. Kamiya, 1963**

A.puttarudriahi Kapur & Munshi 1965

A. sp. 1

***Cryptolaemus* Mulsant, 1853**

C. montrouzieri Mulsant, 1853

***Horniolus* Weise, 1900**

H. nigripes, Miyatake, 1976

H. sororius, Poorani, 2015

***Nephus* Mulsant, 1846**

N. bistillatus (Mulsant) 1853

N lentiformis (Booth) 1991

N. regularis (Sicard) 1929

N. severini (Weise) 1892

N. tagiapatus (Kamiya) 1965

N. sp. 1

***Sasajiscymnus* Vandenberg, 2004**

S. dwipakalpa Ghorpade, 1977

S. luteus (Sicard), 1929

S. pallidicollis (Mulsant), 1853

S. simmondsi Chapin & Ahmad, 1966

S. sp. 1

***Scymnus* Kugelann, 1794**

Subgenus *Scymnus (Neopullus)* Sasaji, 1971

S. (*N.*) *fuscatus* Bohernan, 1859

S. (*N.*) *hoffmanni* Weise, 1879

S. (*N.*) *loebli* Canepari, 1986,

S. (*N.*) sp. 1

Subgenus *Scymnus (Pullus)* Mulsant, 1846

S. (*P.*) *assamensis* Canepari, 1986

S. (*P.*) *bengalicus* Canepari, 1986

S. (*P.*) *besucheti* Canepari, 1986

S. (*P.*) *bourdilloni* (Kapur), 1958

S. (*P.*) *castaneus* Sicard, 1965

S. (*P.*) *ceylonicus* Motschulsky, 1858

S. (*P.*) *coccivora* Ayyar, 1925

S. (*P.*) *facetus* Canepari, 1986

S. (*P.*) *giganteus* Kamiya, 1961

S. (*P.*) *harejoides* (Sicard), 1911

S. (*P.*) *hilaris* Motschulsky, 1858

S. (*P.*) *hingstoni* (Kapur), 1963

S. (*P.*) *impexus* (Mulsant), 1850

S. (*P.*) *kawamurai* (Ohta), 1929

S. (*P.*) *latemaculatus* Motschulsky, 1858

S. (*P.*) *meghalayae* Canepari, 1986

S. (*P.*) *nepalensis* Bielawski, 1971

S. (*P.*) *nymphaeus* (Kapur & Munshi), 1970

S. (*P.*) *o-nigrum* Mulsant, 1853

S. (*P.*) *posticalis* Sicard, 1913

S. (*P.*) *pyrocheilus* Mulsant, 1853

S. (*P.*) *quadrillum* Motschulsky, 1858

S. (*P.*) *rajeswariae* Poorani, 2015

S. (*P.*) *sapporensis* (Ohta), 1929

S. (*P.*) *sodalis* (Weise), 1923

S. (*P.*) *testacecollis* (Kapur), 1963

S. (*P.*) *victoris* Crotch, 1858

S. (*P.*) *victoris unimaculata* Korschefsky, 1934

S. (*P.*) *uninotata* (Gorham), 1894

S. (*P.*) *utilis* Hoang, 1982

S. (*P.*) *xerampelinus* Mulsant, 1853

S. (*P.*) *zonatus* (Sicard), 1911

S. (*P.*) sp. 1

S. (*P.*) sp. 2

S. (*P.*) sp. 3

S. (*P.*) sp. 4

S. (*P.*) sp. 5

S. (*P.*) sp. 6

S. (*P.*) sp. 7

S. (*P.*) sp. 8

S. (*P.*) sp. 9

S. (*P.*) sp. 10

Subgenus *Scymnus (Scymnus)* Kugelann, 1794

S. (*S.*) *andrewesi* Sicard, 1911

S. (*S.*) *apiciflavus* (Motschulsky), 1858

S. (*S.*) *indicus* Weise,1908

S. (*S.*) *lepidulus* Motschulsky, 1858

S. (*S.*) *levaillanti* (Mulsant), 1850

S. (*S.*) *nubilus* Mulsant, 1850

S. (*S.*) *tristigmaticus* Gorham, 1895

S. (*S.*) *venalis* Mulsant, 1853

Species *incertae sedis*

Scymnus saciformis Motschulsky, 1858

Scymnus sp. 2

Subgenus not known

seriatus Weise, 1895

Tribe Stethorini

Genus / Species

***Parastethorus* Pang and Mao, 1975**

P. Indira (Kapur), 1950

***Stethorus* Weise, 1885**

Subgenus *Stethorus* (*Allostethorus*), Iablokoff-Khnzorian, 1972

S. (*A.*) *forficatus* Poorani, 2017

S. (*A.*) *pauperculus* (Weise), 1895

S. (*A.*) *tetranychi* Kapur, 1948

S. (*A.*) sp. 1

Subgenus *Stethorus* (*Stethorus*)

S. (*S.*) *gilvifrons* (Mulsant), 1850

S. (*S.*) *parcepunctatus* Kapur, 1948

S. (*S.*) *rani* Kapur, 1948

S. (*S.*) *aptus* Kapur, 1948

S. (*S.*) sp. 1

Species *incertae sedis*

S. keralicus Kapur, 1961

SYSTEMATICS OF THE TRIBES SCYMNINI AND STETHORINI (COLEOPTERA: COCCINELLIDAE) FROM SOUTH INDIA

by

VIDYA C.V.

(2014-21-111)

ABSTRACT OF THE THESIS

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ABSTRACT

Family Coccinellidae, the lady beetles, belong to the superfamily Coccinelloidea of the order Coleoptera and comprises approximately 6000 described species worldwide. Tribes Scymnini and Stethorini of the subfamily Scymninae of Coccinellidae are economically important predators successfully used in the biological control programmes of sucking pests of crops. Members of Scymnini are mainly predators of aphids, mealybugs, whiteflies and scales, whereas Stethorini are specific to mites. Though the fauna of Scymnini and Stethorini in India is species rich, it is poorly studied.

The present investigation on "Systematics of the tribes Scymnini and Stethorini (Coleoptera: Coccinellidae) from south India" was carried out during 2015-17. The objectives include the following: (1) taxonomy of the tribes Scymnini and Stethorini associated with sucking pests in different agricultural ecosystems of south India, (2) prepare a key to the species of Scymnini and Stethorini and (3) generate DNA barcode for different species of Stethorini.

Purposive surveys were undertaken across different districts of Kerala, Karnataka and Tamil Nadu covering 47 locations and 64 crops under different agricultural ecosystems. Beetles and immature stages of Scymnini and Stethorini were collected along with the associated prey. Immature stages of Scymnini and Stethorini were reared to adults. The specimens were then mounted, labeled and preserved as per standard procedures. The beetles were dissected and the taxonomic characters *viz*., antenna, mouth parts, prosternum, tarsus, post coxal line, male and female genitalia were studied and illustrated. The specimens were identified up to species level. Descriptions, illustrations and key to genera and species of Scymnini and Stethorini of southern India were prepared.

The study encompasses 28 species of Scymnini of which six are putative new species. Two species are recorded for the first time in India and two species each from south India and Kerala are new records. The genera treated under Scymnini include *Axinoscymnus*, *Cryptolaemus*, *Horniolus*, *Nephus*,

Sasajiscymnus and *Scymnus*. The genus *Scymnus,* represented by 20 species, of which 18 species are placed in three subgenera *viz*., *Scymnus, Neopullus* and *Pullus*. Two species are treated separately, as these differ distinctly from the known subgenera. The genus *Nephus* is represented by three species, *Axinoscymnus* with two species and *Cryptolaemus*, *Horniolus* and *Sasajiscymnus* with one species each.

Stethorini are represented by 10 species in two genera: *Stethorus* and *Parastethorus.* Two putative new species of the tribe are described. Six species of Stethorini are new reports for Kerala. Two subgenera recognized under the genus *Stethorus* are *Stethorus* and *Allostethorus.* represented by four species each. *Stethorus keralicus*, one of the most common species, has been treated separately in this study, as its characters are not in agreement with the known subgenera. The genus *Parastethorus* is represented by only one species.

The prey ranges of Scymnini and Stethorini were documented. Species distribution map were prepared for the species studied. Twenty one species of prey in four families *viz*., Aphididae, Pseudococcidae, Aleyrodidae and Diaspididae were recorded in association with the tribe Scymnini. Two new prey records for Scymnini are *Toxoptera odinae* for *Scymnus pyrocheilus* and *Saccharicoccus sacchari* for *Nephus tagiapatus*. Among Scymnini, *Scymnus coccivora* and *S. saciformis* are widely distributed with wider host range of six species as prey, while species of *Axinoscymnus,* though widely distributed, is specific to whiteflies. Among Stethorini, *Stethorus pauperculus* was found to be the predominant species with wider host range, while *Stethorus keralicus* was specific to *Raoiella indica*. New prey records for Stethorini includes *Tetranychus okinawanus* and *T. truncatus* for *Stethorus forficatus*; *T. macfarlanei* for *S. pauperculus* and *Eutetranychus orientalis* for *Parastethorus indira*.

For barcoding the species of Stethorini, DNA was isolated using Qiagen DNeasy blood and tissue kit and the *COI* locus was amplified and sequenced. The sequences were aligned and characteristic barcode gaps were identified for

Parastethorus indira, *Stethorus forficatus*, *S. pauperculus*, *S. rani*, *S. keralicus*, *S.* (*Allostethorus*) sp. 1 and *S.* (*Stethorus*) sp.1. Pairwise distances between the sequences were analysed which showed that intraspecific divergence ranged between 0.00 to 0.03, while the interspecific distance ranged between 0.14 to 0.24. A phylogenetic tree was constructed with 21 sequences in MEGA 7 using maximum likelihood tree method. The sequences were submitted to GenBank (NCBI) and to BOLD for the generation of species specific barcodes.

The study identified 38 species of predatory coccinellids in the tribe Scymnini and Stethorini in association with aphids, mealybugs, whiteflies, scales and mites, which are serious pests of crops. Knowledge on the taxonomy of these predators and their prey range throws light on the potential of the above groups in biocontrol of sucking pests