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Effect of weather parameters on incidence of citrus leaf miner, *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) and its natural enemies in three commercially grown citrus cultivars

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ABSTRACT: Studies on the incidence of citrus leaf miner (CLM), *Phyllocnistis citrella* Stainton, species composition of its bioagents, percentage parasitism and the impact of weather parameters on their incidence on three major citrus cultivars, showed that higher levels of *P. citrella* infestation was found on acid lime and Nagpur mandarin cultivars than on mosambi and higher levels of infestation were observed during August-October and February-April. Different stages of *parasitoids and predators* were collected from leaf miner infested twigs. Parasitisation rates were high during *Hasta* season (October-early December) and least during *Mrig* season (June – July). Acid lime cultivar recorded up to 4.60 parasitized CLM larvae per 10 leaves, while on mosambi it was only 0.65. Maximum temperature was found to have significant negative correlation towards the CLM infestation as well as parasitisation rate on the three cultivars, while relative humidity was found to have significant positive role in favoring the incidence of CLM.

Keywords: Bioagent composition, parasitism levels, population fluctuation, *Phyllocnistis citrella*, weather parameters

INTRODUCTION

The citrus leaf miner (CLM), *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae), was first described in Calcutta, India in 1856 (Stainton, 1856). Among 27 major species of insects and mites, *P. citrella* is the most serious pest of citrus, particularly on nursery and young plantations during hot and dry climatic conditions (Sharma *et al*., 2006). The larvae of *P.*

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citrella mine in leaf tissues of any citrus and related species (Heppner, 1993), and the larval feeding results in distorted and reduced young shoots of the citrus plants. Heavy infestation of *P. citrella* can severely damage young citrus trees in the field or in nurseries, while the damage is less in mature trees (Garcia-Marí *et al.,* 2002). Damage to host plants is incited by direct feeding and by providing an infection site for *Xanthomonas axonopodis* pv. *citri*, a bacterium that causes citrus canker (Jesus *et al*., 2006).

Various control methods have been reported for the management of citrus leaf miner including cultural practices, chemical control, use of petroleum spray oils and biological control (Shivankar *et al*., 2002; Rao and Shivankar, 2002; Jayanthi and Verghese, 2004). Over 80 hymenopteran species, mostly chalcidids, have been recorded to parasitize citrus leaf miner throughout the world (Schauff *et al*., 1998). The aim of this study was to monitor the seasonal abundance of citrus leaf miner, its bioagents and parasitism on major three citrus cultivars *viz*., Nagpur mandarin, acid lime and sweet orange (mosambi) as well as to correlate pest-parasitoid abundance with weather factors.

MATERIALS AND METHODS

In order to estimate the incidence levels of citrus leaf miner, species composition of bioagents and percent parasitism levels, fixed plot surveys were carried out at monthly intervals by collecting 4 flushes (each with 10-15 leaves from north, south, east and west direction in a tree) from ten randomly selected trees of *Citrus reticulata* Blanco (Nagpur mandarin), *Citrus aurantifolia* Swingle (acid lime) and *Citrus sinensis* (L.) (mosambi) for a total of 40 flushes (or 300-400 leaves) per cultivar at NRCC farm, Nagpur. No insecticide sprays were applied during the period of the study in the fixed blocks. Collected leaf samples were stored in properly labelled paper bags, in programmable environmental chamber (Remi scientific Limited) at 24±2^{0}C and RH of 65±5 per cent and were examined under the stereozoom microscope (Olympus SZX16) to determine the presence of mines (either occupied or abandoned), eggs, larvae and pupae of the citrus leaf miner, live and dead, as well as parasitoid immature stages. Leaves containing parasitized individuals of *P. citrella* were placed individually in plastic petridishes with water soaked cotton. Adults on emergence were collected and preserved in 70 per cent alcohol and got identified.

Predators including spiders observed on the surveyed trees were hand collected in glass vials containing ethyl alcohol (75 %) and brought to the laboratory for identification. The percentage parasitism of the samples was calculated as the ratio of the number of the parasitized host larvae and pupae to the total number of all host stages. Relative abundance of major bioagents including spiders was also expressed as percentage over the total bioagent collections obtained during the period of study.

The data of weather factors (maximum temperature, minimum temperature, relative humidity, rainfall) was obtained from www.*imdnagpur.gov.in.* The per cent infestation (CLM) and parasitization data were then correlated with temperature (maximum and minimum temperature), rainfall and humidity to find out any role of weather parameters on the incidence of CLM.

RESULTS

The citrus orchard at NRCC, Nagpur was sampled twelve times between October, 2013 and September, 2014 and out of 4305, 4133 and 3487 leaves of Nagpur mandarin(6 years old), acid lime (5 years old) and sweet orange (8 years old) examined, 1094,1131 and 804 leaves were found infested by *P. citrella*.

Per cent leaf miner infestation: In examination of leaf samples from three citrus cultivars, presence of any stages of *P. citrella* was not/the least observed during early May- early July in all the three cultivars. While there was abundant infestation during October - November, 2013 followed by Feb – April and late July-September, 2014. Results of this study showed that significantly more *P. citrella* infestation was recorded on acid lime and Nagpur mandarin cultivars than on mosambi (Fig.1). On Nagpur mandarin trees, two peaks of live immature stages were recorded *viz*., August-September and February with 51.30, 60.90 and 41.99 per cent infestation, respectively. In acid lime cultivar, similar trend of infestation levels were observed with peaks from July-September and March with the highest infestation levels of 72.33% during the month of September. In comparison, the lowest levels of infestation were observed in Mosambi cultivar with the highest infestation levels of 37.22 per cent during the month of February and followed by September-October months during 2013-14.

The present results have revealed importance of temperature and relative humidity in bringing about change in incidence of CLM in the cultivars. Maximum temperature was found to have significant negative correlation towards the CLM infestation on the three cultivars. As the winter temperature increased during November to December, the per cent leaf miner infestation also decreased simultaneously. But with gradual increase in temperature during February to March, again a peak in per cent infestation was observed. It was also clearly evident that the relative humidity had a major role in favoring the incidence of citrus leaf miner (Table.1). Relation of incidence with rainfall was positive but not significant in all the three cultivars under study.

Table.1 Correlation of citrus leaf miner incidence and parasitism levels on three cultivars with weather parameters

Cultivars	Mean Max.Temp	Mean Min.Temp	Mean Humidity	Rainfall
Nagpur mandarin	-0.58*	-0.04	0.67*	0.48
Acid lime	-0.63*	-0.35	0.72*	0.04
Mosambi	-0.59*	-0.18	0.89*	0.22

*** Significant at 5%**

Bioagents and percent parasitism: The parasitoid complex of *P. citrella* consisted of *Citrostichus phyllocnistoides* Narayanan*, Cirrospilus quadristriatus* (SubbaRao and Ramamani)*, **Elasmus brevicornis*** Gahan, ***Sympiesis striatipes*** (Ashmead) etc. Larva of *Mallada desjardinsi* (Navas) and adult stages of *Coccinella septumpunctata* (Lin.), *Serangium parcesetosum* Sicard were also found in the citrus ecosystem attacking larval stages of citrus leaf miner (Table.2). Three different species of spider's *viz.*, *Neoscona* cf. *theisi, Clubiona* sp. and *Thyene imperialis* were collected and constituted 7 per cent of the total bioagent collection. Similarly, grubs of coccinellid predators and *M. desjardinsi* larvae were found feeding on the larvae in mines which were exposed due to spider attack in the mines.

Relative abundance of the bioagents were also documented (Fig.2). Among them, *C. quadristriatus* was the predominant one apart from five unidentified *Cirrospilus* sp. in the collection. *C. phyllocnistoides* constituted 60 per cent of the total parasitoid complex and 30

Table.2 Natural enemies associated with citrus leaf miner, *P.citrella* during Oct, 2013-Sept, 2014

Bioagent	Order	Family
Parasitoids		
Citrostichus phyllocnistoides Narayanan	Hymenoptera	Eulophidae
Cirrospilus quadristriatus (SubbaRao and Ramamani)	Hymenoptera	Eulophidae
Cirrospilus sp. (Unidentified)	Hymenoptera	Eulophidae
Elasmus brevicornisGahan	Hymenoptera	Eulophidae
Sympiesis striatipes (Ashmead)	Hymenoptera	Eulophidae
Predators		
Mallada desjardinsi (Navas)	Neuroptera	Chrysopidae
Coccinella septumpunctata (Lin.)	Coleoptera	Coccinellidae
Serangium parcesetosum Sicard	Coleoptera	Coccinellidae
Spiders		
Neoscona cf. *theisi* (Walckenaer, 1842)	Araneae	Araneidae
Neoscona sp. 1	-do-	Araneidae
Clubiona sp.	-do-	Clubionidae
Thyene imperialis (Rossi, 1846)	-do-	Salticidae

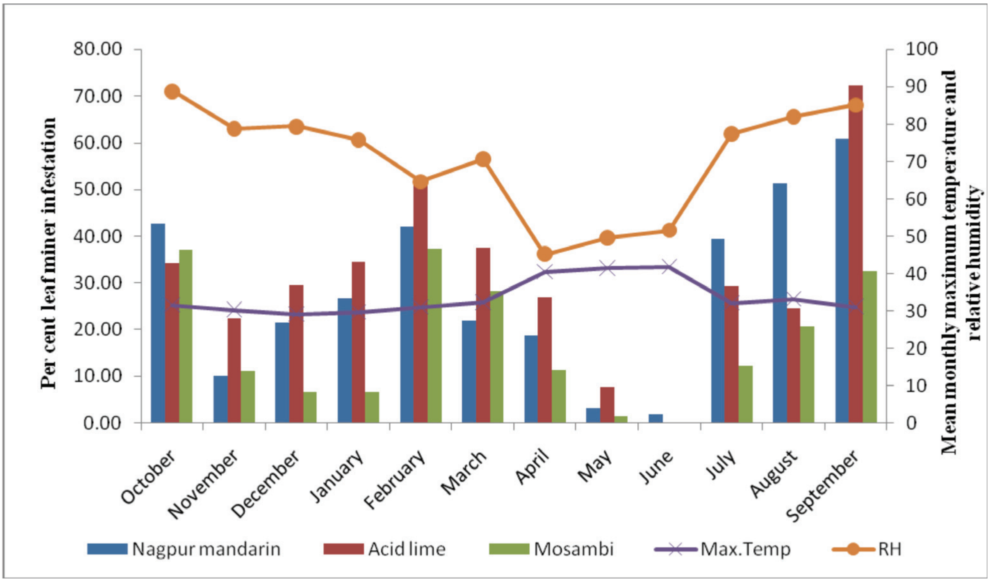

Fig.1. Percent infestation by citrus leaf miner, *P. citrella* and impact of major weather parameters on Nagpur mandarin, Acid lime and Mosambi cultivars during October, 2013-September, 2014

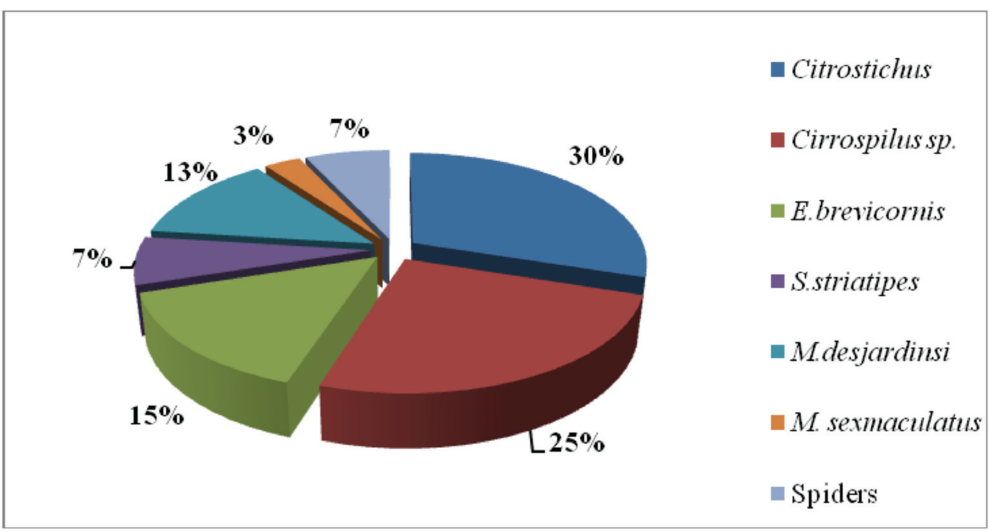

Fig.2 Relative abundance of bioagents recorded on citrus leaf miner from three citrus Cultivars

per cent of total bioagents collected. Diverse collection of Genus *Cirrospilus* including *C.quadristriatus* was obtained and comprised around 25% of total collection. *E. brevicornis* was found as an ecto-larval parasitoid of citrus leaf miner predominant during *Hasta* season. *S. striatipes* accounted for only 7% of the total bioagents collection and was found in low numbers.

The total number of parasitoids collected was maximum on acid lime followed by Nagpur mandarin compared with mosambi, probably due to the higher leaf miner population registered in the former cultivars. Maximum levels of parasitism were recorded during the months of October to November followed by February to March (Table. 3). Acid lime cultivar recorded up to 4.60 parasitized CLM larvae per 10 leaves while on mosambi, it was only 0.65 per 10 leaves. *C. phyllocnistoides* appeared for the first time in the samples during *Hasta* season *i.e* early October and November, having high rates of parasitism. Later as the winter started parasitism by this parasitoid decreased from December and again reaching its maximum during *Ambia* season *i.e* Feb to March. A complex of *Cirrospilus* sp. was also observed in the samples collected. This study also showed variability in *P. citrella* parasitism on the three commercial citrus cultivars. However, it was significantly higher with 9.45, 9.88 and 6.27 per cent, which were the mean percent parasitism found during the period of study in Nagpur mandarin, acid lime and mosambi cultivars, respectively. In general, a positive relationship

Table.3 Percent parasitism in Nagpur mandarin, Acid lime and Mosambi cultivars during October, 2013-September, 2014

Months	Nagpur mandarin	Acid lime	Mosambi
October	21.00	11.8	13.10
November	12.50	23.5	14.59
December	4.90	9.5	2.76
January	8.40	6.3	3.30
February	9.10	16.8	6.51
March	14.84	11.3	10.42
April	6.49	15.4	7.32
May	0.00	2.6	0.00
June	3.60	0.0	0.00
July	8.80	0.0	1.30
August	12.50	5.6	6.70
September	16.40	10.7	9.30

was evident between *P. citrella* and parasitoid abundance on the three citrus cultivars. An increase in the activity of parasitoids was observed when the average monthly temperature was between 29 to 33æ%C and the relative humidity was between 78 and 88 per cent. The role of spiders in the overall management of *P. citrella* populations was also studied. Maximum temperature was found to have significant impact on parasitisation rates but negative correlation (Table.4) while relative humidity was having positive correlation on parasitisation but not significant. Minimum temperature and rainfall was having negative and positive correlation, respectively *w.r.t* parasitisation on citrus leaf miner but not showing any significant influence.

Table.4 Correlation of parasitism with weather parameters

Cultivars	Mean Max.Temp	Mean Min.Temp	Relative Humidity	Rainfall
Nagpur mandarin	-0.57*	-0.16	0.74*	0.36
Acid lime	-0.63*	-0.35	0.52	0.04
Mosambi	-0.48	-0.18	0.49	0.23

*** Significant at 5%**

DISCUSSION

The citrus trees have generally three flush seasons; spring flush from Feb-April, summer flush from June to August and winter flush from October to November. The seasonal pattern of leaf miner activity was fairly higher with populations peaking during spring and late autumn flush and declining during the winter. Koli *et al.* (1981) observed maximum number of *P. citrella* larvae on citrus during August to October and February to March. The larval population of leaf-miner was higher during August-September than during the rest of the period (Ahmed *et al*. 2013). Knapp *et al*. (1995) and Jac-as *et al*. (1997) pointed out that the differences in susceptibility among different citrus species seem to be related to the flushing patterns of the trees. Acid lime cultivar was found to be highly susceptible to leaf miner attack with the maximum leaf miner infestation recorded in our study. The higher degree of susceptibility of acid lime among citrus cultivars may be induced due to certain anatomical modifications that can increase or decrease interaction between citrus cultivars and CLM (Gassmann and Hare 2005: Muller and Riederer 2005; Mathews *et al.* 2007). Lower preference of *P. citrella* was found on mosambi cultivar and could be due to the fact that mosambi do not develop intense vegetative flushes and consequently the microclimate in their canopy seems to be not ideal for the citrus leaf miner compared to acid lime and Nagpur mandarin.

The present results have revealed importance of temperature and relative humidity in bringing about change in incidence of CLM. High population densities of *P. citrella* are usually recorded in spring and summer due to greater availability of leaf flushes and new shoots, as well as higher temperatures (Pena *et al*. 1996; Legaspi *et al*. 1999). Minimum temperature and relative humidity were the abiotic factors showing the strongest influence in the numbers of *P. citrella* mines and parasitisation.

Many parasitoids were recorded on the eggs and larvae of the leaf miner (Singh, 1993). Among them, *Tetrastichus phyllocnistoides* (Narayanan) and *Ageniaspis* sp. are important, the latter causing upto 80% parasitism (Atwal, 1964). Our collection mainly consisted of eulophid parasitoids, *viz*., *C. phyllocnistoides, Cirrospilus* sp., ***E. brevicornis*** **and** ***S. striatipes.*** *C. phyllocnistoides* is an ectoparasitoid of *P.citrella* and SubbaRao and Ramamani (1965) reported that parasitism by *C. phyllocnistoides* in India started in the fourth week of July, but did not exceed 2 to 4 per cent. Levels increased during the second week of August and during the third and fourth week of August ranging from 40 to 50 per cent. Parasitism levels decreased in the first and second week of September and disappeared by October. *Cirrospilus* Westwood is a large and widespread genus of Eulophinae, with over 130 species worldwide (Noyes, 1998) and has been reported as an ecto-parasitoid of late instar larvae of the CLM (Hoy and Nguyen, 1994) producing a single individual per host. *Sympiesis striatipes* was found in low number and it can be assumed that this parasitoid species have a very low impact on the reduction of pest population.

Parasitism in the orchards generally followed a trend similar to that of *P. citrella* density throughout the spring to winter during the study period. This is in agreement with previous studies, in which the spatial distribution of host and its natural enemies has a great influence on the dynamics of both populations (Jahnke *et al*. 2008) and most natural enemies react to the spatial distribution of their prey (Pedigo 1996). There is considerable difference in the flushing pattern of the three cultivars with regular and heavy flushing in acid lime cultivar and the least in mosambi and hence citrus leaf miner infestation also. Also measures should be taken to conserve the natural bioagents present in the citrus ecosystem especially during *Hasta* season during which per cent parasitization by parasitoids was highest. The present study helps in developing a spray programme based on active period of CLM coinciding with new flush and avoiding sprays during bioagent active periods.

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Semiochemicals from the aggregation site of home invading nuisance pest, *Luprops tristis* (Coleoptera: Tenebrionidae)

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ABSTRACT: *Luprops tristis* (Mupli beetle) is noted for the magnitude of nuisance caused by home invasion in millions prior to monsoon rains and subsequent dormancy inside residential buildings in rubber plantation belts of Kerala state of India, for the last three decades. Return of the new generation beetles into the same shelters used by parent generation strongly suggests the involvement of semiochemicals based at aggregation sites and identification of such semiochemicals may offer alternative management strategies for this nuisance species. In the present study, air borne volatiles from the aggregation site during different phases of dormancy were collected, identified, bioassayed for behavioural response and possible role of identified volatile compounds in the selection of aggregation sites and maintenance of aggregation has been discussed.

KEYWORDS: Mupli beetle, *Luprops tristis*, home invasion, aggregation site, semiochemicals

INTRODUCTION

Litter dwelling detritivore beetle *Luprops tristis* (Fabricius) (Tenebrionidae: Lagriinae: Lupropini), is a serious home invading nuisance pest in the rubber plantation belts of Kerala state of India, for the last three decades. Their massive seasonal invasion in to residential buildings prior to monsoon rains and prolonged presence inside the houses for eight months (Sabu *et al*., 2008) makes them the most dreaded nuisance pest of the region. *L. tristis* breeds and feeds in rubber litter, thick litter stands present in rubber plantations during pre-summer and summer period are the ideal breeding and feeding ground and its biology is synchronised

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with the phenology of annual leaf shedding and leaf sprouting of rubber trees (Sabu and Vinod, 2009a; b). Presence of thousands of hectares of rubber plantations along the western slopes of the South Western Ghats in Kerala, with an astonishing population of *L. tristis* concealed in lower litter layers makes conventional insecticidal chemical based control methods practically impossible.

Since home invasion of the beetle takes place during rainy season, affected people are left with little choice but to kill the home invaded beetles by indoor application of various insecticides. Despite three decades of their wide spread presence in the region, no efficient strategies for controlling the population build up of *L. tristis* have been developed and there is a need to develop environmentally benign control tactics (Aswathi and Sabu, 2011). All across the region, the new generation beetles have been selecting the same sites for aggregation even after the treatment of chemical insecticides in shelters (Sabu *et al*., 2008). It lead to the proposal that the semiochemicals released by the aggregated beetles could be involved in the attraction of new generation beetles to the shelters used by the previous generation, and identification of the semiochemicals prevailing in the aggregation sites may enable development of a pheromone-mediated management programme to control the menace.

MATERIALS AND METHODS

Home invasion of *L. tristis* occurs by April/ May period and the aggregation and dormancy last for eight months. Dormancy phase has been divided into four phases namely initial, mid, last and post-dormancy and the semiochemicals present in the aggregation site were collected during each phase.

Collection of volatile compounds from aggregation sites

Air-borne volatiles were collected using activated charcoal as adsorbent from a rock cave close to a rubber plantation at Kattipara, in Kozhikode district of Kerala state during 2009-2010 period. Selected rock cave is an aggregation site for the beetles for the past 15 years. Adsorbent material was purified following Millar and Sims (1998) and placed in a circular earthen vessel at the site of aggregation. Adsorbent material was retrieved after 72 hours, eluted in n-Hexane (HPLC grade, Fischer scientific), the extract was filtered through Glass-Fibre filter paper (Whatman), evaporated in to 2 ml under room temperature and stored in a freezer at -20º C.

GC-MS Analysis and Identification of volatile compounds

Compounds in the Hexane extract were analyzed with a gas chromatograph (GC) coupled to a mass spectrometer (MS) (Hewlett Packard 5890 series II and Hewlett Packard 5971 series-Mass selective detector) and fitted with a silica capillary column (Agilent, model HP5-MS). Data was acquired under the following GC conditions: Injection: 1µl; running time: 45 minutes; inlet temperature: 250°C, carrier gas: helium at 51 $cm.s^{-1}$, split ratio 13:1, transfer-line Temperature:

280°C, initial temperature: 40°C, initial time: 2 min, rate: 10°C.min^{-1}, final temperature: 260°C. Component identification was made on the basis of mass spectral fragmentation pattern, retention time and comparison with authentic constituent's mass spectral and retention time that matches with Wiley library.

Bioassay for behavioural response

An olfactometer made up of glass with a central chamber and two side chambers connected with glass tubes of length 12 cm and internal diameter1.75cm was employed. A power running aerator system with a regulator was attached to the olfactometer and the air speed in the system was adjusted to 2.5 L min^{-1}, and it was previously humidified and filtered on active charcoal. Commercially available standards for the identified potential compounds were purchased (Alfa Aesar) and n-hexane was used as solvent. Tests, each lasting 15 minutes, were repeated for 5 times using pre-dormancy males and females separately. Chemical standards of identified compounds were placed at the end of one of the arms, using glass fiber filter paper (2x2 cm) impregnated with 5.0 µL of the solution, while the same volume of hexane was used as a control at the end of the other arm. Only insects that reached the arms of the olfactometer and remained near the odour source were considered. Data obtained with insects that reached control and test odour sources were normally distributed and parametric statistics were used for comparison of the data. Variations in number of beetles reaching test chamber and control chamber in each experiment were analysed with one-way ANOVA test. For all analyses, significance was determined at $P<0.05$. Minitab Statistical software version 16 was used for all statistical analysis.

RESULTS

GC-MS profile of the compounds identified from the aggregation sites of *L.tristis* during various phases of aggregation and following post dormancy departure were provided (Fig 1.). Altogether 12 compounds with known semiochemical function in insects were recorded with eight compounds during various phases of dormancy and six compounds after post dormancy return of beetles (Table 1.)

Seven volatile compounds namely, Hexadecane, Pentadecane, Tetradecane, Heptadecane, Decane, Dotriacontane and Hexacosane were identified during the initial phase of dormancy, one volatile fraction representing Pentatriacontane during the mid phase and 6 volatile fractions representing Dotriacontane, 1-Tridecene, 1-Heptadecene, Tridecane, 1-Pentadecene and Hexadecane were recorded after the post dormancy return of the beetles to the rubber plantation litter. No volatile fractions representing compounds with previous report of semiochemical function in insects were recorded during the last phase of dormancy.

Behavioral responses were tested using olfactometer for Hexadecane and Dotriacontane, the major volatile fractions during the early and the post dormancy phase. Both the sexes did not show any behavioural response towards Hexadecane (Test= 2.50 ± 0.97, Control= 2.20 ± 1.48,

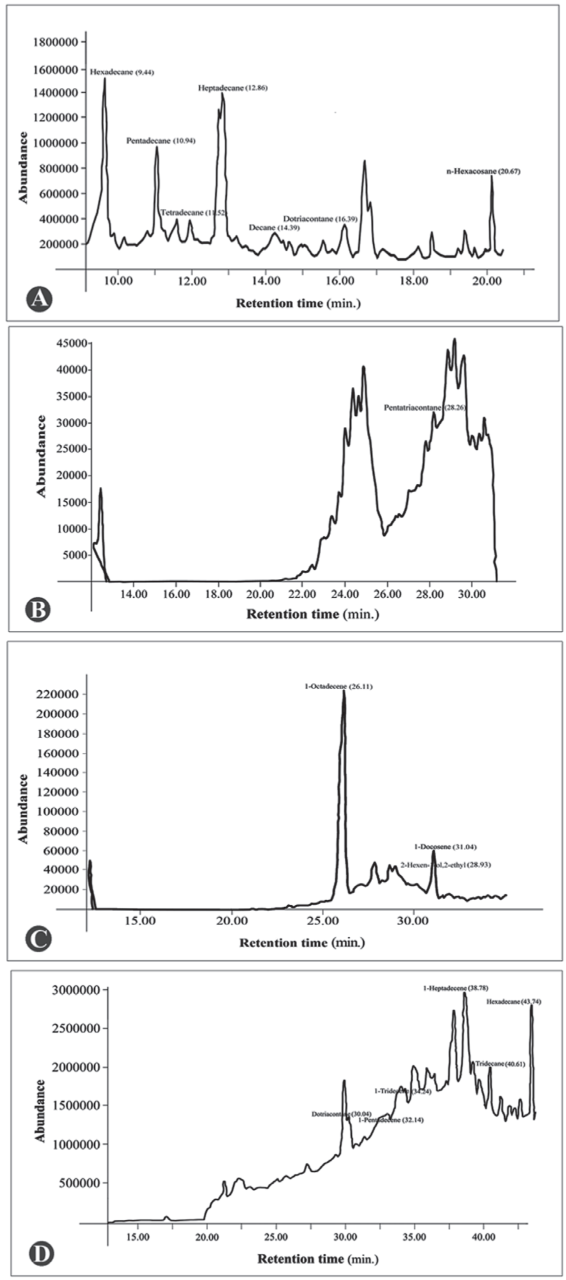

Fig. 1: GC MS profile of volatile samples collected from aggregation site of *Luprops tristis* during different phase of aggregation and dormancy. A-Initial phase,B-midphase, C-final phase and D-after dormancy.

Table 1. List of potential pheromone components identified from the aggregation site of *L. tristis* during different phases of aggregation with supporting literature (1-Initial phase; 2- Mid phase; 3- Last phase and 4 - Post-dormancy.

Sl. No.	Compound	CAS	Function
1.	Hexadecane [1,4]	544-76-3	Aggregation pheromone component Tenebrionidae (Keville and Kannowski, 1975)
2.	1- Heptadecene [4]	6765-39-5	Aggregation pheromone component Tenebrionidae (Keville and Kannowski, 1975)
3.	1-Pentadecene[4]	13360-61-7	Aggregation pheromone component Tenebrionidae (Arnaud *et al*., 2002)
4.	Dotriacontane [1,4]	544-85-4	Cuticular hydrocarbonTenebrionidae (Lockey, 1982; Lockey, 1984)
5.	Hexacosane [1]	630-01-3	Cuticular hydrocarbonTenebrionidae (Lockey, 1982; Lockey, 1984)
6.	1-Tridecene [4]	2437-56-1	Male sex pheromoneTenebrionidae (Geiselhardt *et al.*, 2008)
7.	Pentadecane [1]	629-62-9	Allomone component (Defence substance) Carabidae (Evans, 1988)
8.	Tetradecane [1]	629-59-4	Allomone component(Defence substance) Carabidae (Eisner *et al.*, 1977)
9.	Heptadecane [1]	629-78-7	Allomone component (Defence substance) Carabidae (Eisner *et al.*, 1977; Evans, 1988; Attygalle *et al.*, 1992)
10.	Decane[1]	124-18-5	Allomone component (Defence substance) Carabidae (Evans, 1988)
11.	Tridecane[4]	629-50-5	Allomone component (Defence substance) Carabidae (Eisner *et al.*, 1977)
12.	Pentatriacontane [2]	630-07-9	Cuticular Hydrocarbon Psyllidae (Guédot *et al.*, 2009)

p>0.05 for males and Test= 2.40 ± 1.18, Control= 2.40 ± 0.97, p>0.05 for females) and Dotriacontane (Test= 1.5 ± 1.08, Control= 1.7 ± 1.70, p>0.05 for males and Test= 2.0 ± 1.15, Control= 1.80 ± 1.32, p>0.05 for females).

DISCUSSION

Study revealed the presence of 10 compounds with aggregation property and defensive functions and a distinct seasonality in the occurrence of compounds with 7 volatile fractions in the initial phase, 6 after the post dormancy return of beetles, one in the midphase and no fractions in last phase of dormancy. Out of the 10 major compounds identified, no compound was present during all the four phases of dormancy indicating variations in the semiochemicals during different phases of dormancy. Compounds present during initial and post dormancy phase were mainly aggregation pheromone components namely, Hexadecane, 1-Heptadecene (Keville and Kannowski, 1975), 1-Pentadecene (Arnaud *et al*., 2002), 1-Tridecene (Geiselhardt *et al*., 2008) and cuticular hydrocarbons, Dotriacontane and Hexacosane (Lockey, 1982; Lockey, 1984). Functions of the two cuticular hydrocarbons present at initial phase and one (Dotriacontane) at post dormancy phase is unknown. Since cuticular hydrocarbons associated with more volatile compounds function as a pheromone in many aspects of social life (Walter *et al*., 1993), as a spacing pheromone (Howard and Blomquist, 1982), and as an aggregation pheromone (Rivault et al., 1998), it is highly likely that these two cuticular hydrocarbons, (Dotriacontane and Hexacosane) also play a major role in the aggregation behaviour of L.tristis. Pentadecane (Evans, 1988), Tetradecane (Eisner *et al*., 1977), Decane (Attygalle *et al*., 1992) and Heptadecane (Evans, 1988), which are reported as allomone components with defensive function in Carabids would be released to repel the predators that might prey upon the aggregated beetles. Compounds with aggregation property, defensive function and spacing property were present in the initial phase indicating that these are released to ensure maintenance of aggregation in the site. It is likely that the compounds with aggregation property (Hexadecane) present during the initial and post dormancy phase contributes towards attraction of beetles to the sites and maintenance of the aggregation in the shelter which remained unoccupied by beetles for 3-4 months and cuticular hydrocarbons in spacing out the beetles in the aggregation site.

Pentatriacontane, the only compound identified during the mid phase of dormancy was reported earlier as cuticular hydrocarbon in Psyllidae (Guédot *et al*., 2009) and no major compounds were recorded during the mid and last phase of aggregation and dormancy. Lack of compounds with aggregation and defensive property during mid phase and towards the end of dormancy suggests that after the establishment of aggregation and dormancy, such compounds are not released after initial phase. Presence of similar compounds again after the post dormancy retarding phase shows that release of such compounds occur before the departure of post-dormancy beetles from the aggregation shelters and such compounds left behind may be the cues for the next generation beetles to locate the shelters which have been used by their parent generation. Presence of Dotriacontane and Hexadecane as major fractions in the early phase and after the post dormancy retarding phase indicates that these two compounds have play a major role in maintaining the aggregation and recognising the aggregation sites by the new generation beetles. However, absence of behavioural response towards the two major fractions, Dotriacontane and Hexadecane indicates that L.tristis aggregations are not solely managed by individual volatile chemicals like aggregation pheromones as reported in many other tenebrionids, but it involves interaction or synergistic effects of more than one compound which may or may not be previously reported as insect semiochemicals.

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Contribution to the fauna of Encyrtidae (Hymenoptera: Chalcidoidea) of the Andaman and Nicobar Islands, with description of four new species

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ABSTRACT: Four new species of Encyrtidae (Hymenoptera) are described and twenty-three species are recorded, of which seven species are newly recorded from the Andaman Islands (India). The new species described are: *Ageniaspis montanus* Hayat, sp. nov., *Coccidencyrtus jazirah* Hayat, sp. nov., *Ooencyrtus zenon* Hayat, sp. nov. and *Paraphaenodiscus nesiotes* Hayat, sp. nov. The following five genera are recorded for the first time from the Andaman and Nicobar Islands: *Ageniaspis* Dahlbom, *Amicencyrtus* Hayat, *Helegonatopus* Perkins, *Indaphycus* Hayat and *Paraphaenodiscus* Girault. ©2014 Association for Advancement of Entomology

KEYWORDS: Hymenoptera, Encyrtidae, new records, new species, Andaman Islands, India.

INTRODUCTION

The fauna of Encyrtidae (Hymenoptera: Chalcidoidea) from the Andaman and Nicobar Islands (India) until recently was poorly known. In recent years, Manickavasagam and Rameshkumar (2013) and Hayat and Veenakumari (2013, 2014a, b) added several genera and species. This paper is a continuation of our contributions to the encyrtid fauna of the Andaman and Nicobar Islands. We record 23 species, of which seven species are newly recorded from Andaman Islands, and describe four new species. Further, five genera are also newly recorded from these islands. The total number of known species now stands at 82 in 46 genera (see list of species of Encyrtidae from the Andaman and Nicobar Islands given in this paper).

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METHODS

Hayat (2006) is followed for terminology, except for the use of the terms 'mesosoma' for the thorax plus propodeum and 'metasoma' for the petiole plus gaster. Only body lengths are given in millimetres; other measurements are relative, taken from the divisions of a linear scale of a micrometer placed in the eye piece of a stereozoom binocular microscope for card mounted specimens at 10× zoom 8 magnification (1 division = 0.001234 mm), and placed in the eye piece of a compound microscope at either 100× magnification (1 division = 0.00988 mm) or at 400× magnification (1 division = 0.0025 mm) as noted in the text.

Citations to the species are not given as these are available in Hayat (2006) and later publications. Under "Records of species", citations to the first record of or description of a species based on material from the Andaman and Nicobar Islands, is not given as this is provided in the "List of Encyrtidae from Andaman and Nicobar Islands". The genera and species newly recorded from the Andaman and Nicobar Islands are, however, indicated in square brackets following the name of the species.

The following abbreviations are used:

ANI = Andaman and Nicobar Islands. This abbreviation is used on the data labels of the specimens.

F1, F2, etc. = Funicle segments 1, 2, etc.

(MT) = Malaise Trap. (This and two other abbreviations placed in brackets are used under 'Material examined' section to indicate the method of collection of the specimens.)

OCL = Minimum distance between a posterior ocellus and the occipital margin.

OOL = Minimum distance between a posterior ocellus and the corresponding eye margin.

POL = Minimum distance between the posterior ocelli.

(SN) = Sweep Net.

TI, TII, etc. = Tergites 1, 2, etc. of gaster.

(YPT) = Yellow Pan Trap.

The following acronyms are used for the depositories:

NBAIR = National Bureau of Agricultural Insect Resources, Bengaluru, India.

ZDAMU = Insect Collections, Department of Zoology, Aligarh Muslim University, Aligarh, India.

RESULTS AND DISCUSSION

Description of new species

1. *Ageniaspis montanus* Hayat, sp. nov. (Figs 1–7)

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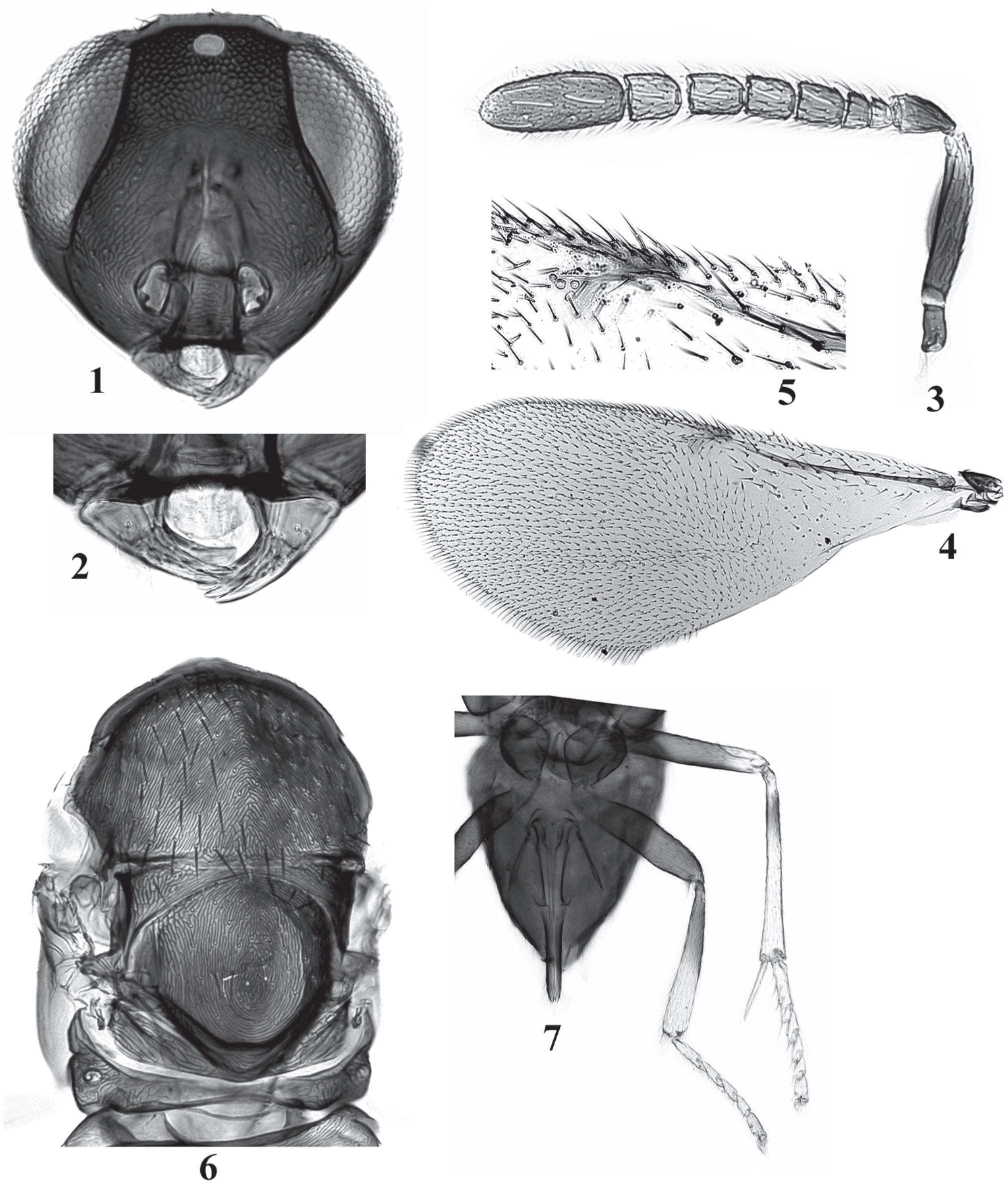
Female

Holotype. Length, 0.86 mm. Head dark brown with bluish shine. Antenna with radicle dark brown; scape dark brown with apex white; pedicel dark brown with apex white; funicle segments, in outer aspect, infuscate brown, with lower two-thirds of F1 and lower third of F2, white; in inner aspect, F1 and F2 same as in outer aspect, but F4–F6 largely white except brown margins; clava brown. Mesosoma dark brown; mesothoracic dorsum matt. Wings hyaline. Fore leg with coxa dark brown; trochanter white; femur dark brown with base and apex white; tibia brown with base and apical half white. Mid leg with coxa dark brown; trochanter white; femur dark brown with base and apex white; tibia white with a dark brown sub-basal band. Hind leg with coxa dark brown; trochanter white; femur dark brown; tibia in about basal three-fifths dark brown and apical two-fifths white. Metasoma dark brown; ovipositor sheaths dark brown.

Head. Occipital margin sharp; head, in frontal view (Fig. 1), 1.17× as broad as high; frontovertex width 0.38× head width; mouth fossa width nearly as wide as frontovertex width; eye height 2× malar space; frontovertex with raised, polygonal reticulate sculpture and with minute setigerous punctures; face on sides of scrobes with cells obliquely oriented, and elongate; malar space with lineolate reticulate sculpture; setae on head brown; eye setose, setae hyaline, and each seta at least about as long as a facet diameter. Mandible (Fig. 2) slightly curved and narrowed towards apex, with two pointed teeth and an apically truncate third tooth. Antenna (Fig. 3) with scape 3.8× as long as broad (measured in the second antenna, not illustrated; in Fig. 3, the scape is slightly tilted laterally, hence appears slightly more than 4× as long as broad), as long as frontovertex width, slightly more than 3× as long as pedicel, and distinctly longer (1.18×) than clava; pedicel 1.47× as long as broad, and longer than F1 and F2 combined; F1 transverse, shorter and narrower than F2; F2 transverse; F3 1.75× as long as and slightly broader than, F2; F3–F6 each slightly longer than broad; clava solid (= unsegmented), 2.57× as long as broad, and slightly shorter than F4–F6 combined; sensilla absent on F1 and F2. *Relative measurements* (slide, at 100×): head frontal width, 34; head frontal height, 29; frontovertex width, 13; mouth fossa width, 12; eye height, 20; malar space, 10; antennal scape length, 13. (slide, at 400×), antennal segments, length (width)–scape, 53.5 (14); pedicel, 17 (11.5); F1, 7 (9); F2, 8 (11); F3, 14 (12); F4, 15 (12); F5, 16 (12.5); F6, 16 (14); clava, 45 (17.5).

Mesosoma (Fig. 6). Mesoscutum and scutellum with lineolate reticulate sculpture; setae all dark brown. Fore wing (Fig. 4) 2.28× as long as broad; costal cell with a line of setae in distal two-fifths on dorsal surface, ventral surface with a line of setae in about distal third, which



FIGURES 1–7. ***Ageniaspis montanus*** **Hayat, sp. nov., holotype, female: 1, head frontal view; 2, mandibles; 3, antenna; 4, fore wing; 5, distal venation of fore wing; 6, mesosoma; 7, metasoma with mid and hind legs.**

become two lines in proximal two-thirds; basal triangle largely bare; filum spinosum represented by a single spine; relative lengths of marginal, postmarginal and stigmal veins, 13:29:14 (Fig. 5). Hind wing 3.46× as long as broad. Mid tibia 3× as long as mid basitarsus; mid tibial spur as long as mid basitarsus (Fig. 7). *Relative measurements* (slide, at 100×): mesosoma length, 40; mid tibia length, 30; mid basitarsus length, 10; mid tibial spur length, 10.

Metasoma (Fig. 7). Ovipositor exserted to 0.12× gaster length. *Relative measurements* (slide, at 100×): metasoma length, 38; ovipositor length, 28; third valvula length, 15. [Ovipositor very slightly longer than mid tibia; third valvula 1.5× as long as both mid tibial spur and mid basitarsus.]

Male: Unknown.

Material examined: Holotype, female (on slide under 4 coverslips, slide No. EH.1720), labelled "INDIA: ANI: South Andaman, Mt. Harriet, 1.ii.2013 (SN), Coll. K. Veenakumari" (NBAIR; registration No. ICAR/NBAIR/EN.35).

Distribution: India: Andaman and Nicobar Islands.

Etymology: Latin, *montanus* = belonging to a mountain.

Comments: This new species, *Ageniaspis montanus* Hayat, sp. nov., is similar to *A. fuscicollis* (Dalman) (see Mercet, 1921: 336, fig. 144; Trjapitzin, 1989: 355, fig. 365), but differs mainly in the dimensions of antennal segments, and in having the ovipositor exserted to 0.12× gaster length. In the new species, scape 3.8× as long as broad and F3–F6 each longer than broad. In *fuscicollis:* scape about 3× as long as broad, and F3–F6 each quadrate to broader than long.

The genus *Ageniaspis* Dahlbom is newly recorded from the Andaman and Nicobar Islands.

2. *Coccidencyrtus jazirah* Hayat, sp. nov. (Figs 8–13)

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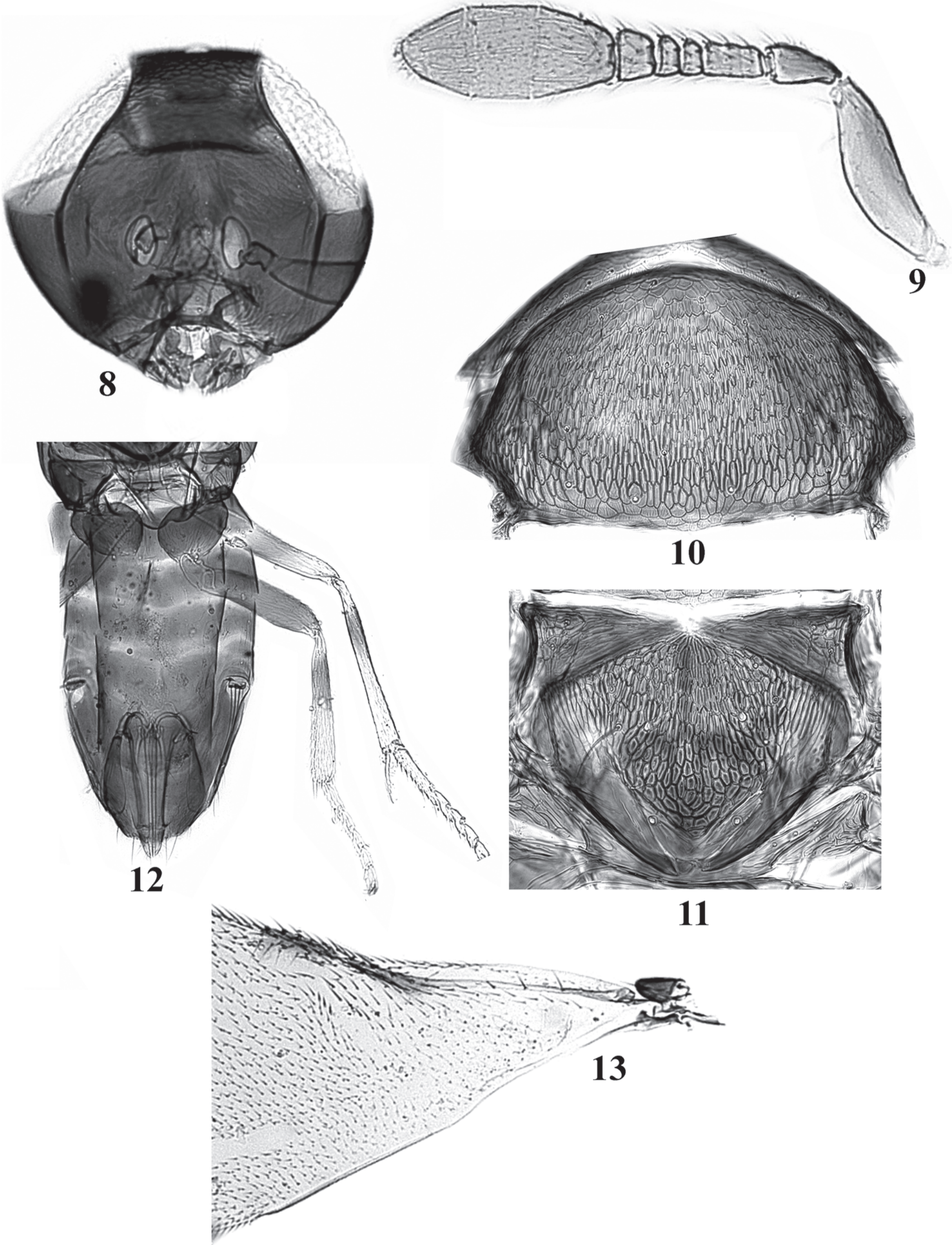
The metallic shine of this species was not noted prior to mounting the specimen on slide.

Female

Holotype. Length, mesosoma plus metasoma, 0.69 mm. Body completely dark brown. Antenna with scape yellow with upper third brown; pedicel dark brown, apex white; funicle yellowish brown; clava pale brown. Wings hyaline; fore wing with parastigma, marginal and postmarginal veins, dark brown. Fore leg with coxa, femur except white apex, and tibia except white apical half or so, dark brown. Mid leg with coxa, femur except white apical fourth, dark brown; tibia with a dark brown band except white base and apical half. Hind leg with coxa and femur dark brown; tibia with a dark brown band, except white base and apical half.



FIGURES 8–13. ***Coccidencyrtus jazirah*** **Hayat, sp. nov., holotype, female: 8, head frontal view; 9, antenna; 10, mesoscutum; 11, axillae and scutellum; 12, propodeum and metasoma with mid and hind legs; 13, fore wing, basal half.**

Head (Fig. 8), in frontal view, 1.27× as broad as high; frontovertex width 0.34× head width; antennal torulus with upper margin in line with lower margin of eye; distance between torulus to mouth margin at least slightly more than torulus height; mouth fossa 1.12× frontovertex width; eye height slightly more (1.18×) than malar space; frontovertex with raised, polygonal reticulate sculpture; face up to toruli with fine, transversely elongate reticulations, from upper level of toruli to mouth margin with slightly obliquely oriented, fine, longitudinally elongate reticulations; setae sparse and hyaline; eye setose, setae hyaline, and each seta shorter than a facet diameter. Mandible (Fig. 8) with one pointed tooth and a broad dorsal truncation. Antenna (Fig. 9) with scape 3.28× as long as broad; pedicel 1.7× as long as broad, and slightly longer than F1–3 combined; F1–3 fused, with sutures faintly indicated; F1–5 transverse, and F5 two-thirds the length of F6; F6 1.44× as broad as long; clava slightly shorter than pedicel and funicle combined. *Relative measurements* (slide, at 100×): head frontal width, 28; head frontal height, 22; frontovertex width, 9.75; mouth fossa width, 11; torulus height, 4; inter-torular distance, 5; torulus mouth margin distance, 5; eye height, 13; malar space, 11. (slide, at 400×) antennal segments length (width)–scape, 46 (14); pedicel, 17 (10); F1–3, 14 (8); F4, 5.5 (9); F5, 6 (10); F6, 9 (13); pedicel plus funicle, 55; clava, 52.5.

Mesosoma. Pronotum with irregular, transversely elongate, reticulate sculpture; mesoscutum with raised, small, longitudinally elongate reticulations, the cells slightly larger posteriorly, but appearing finely lineolate reticulate at lower magnifications (Fig. 10); scutellum in a triangular area with deep polygonal, longitudinally elongate reticulations, the cells in posterior third larger, and aciculate, laterally in about anterior half with lineolate reticulate sculpture, but sides and apex smooth (Fig. 11); setae brown; pronotal collar with a line of setae, with one seta at each posterolateral corner long; mesoscutum with 24 setae; each axilla with 2 setae; scutellum with 3 + 3 setae; scutellar sensilla located in about anterior third of scutellum. Fore wing 2.42× as long as broad; costal cell with a line of setae on distal half of dorsal surface, and ventral surface with two lines of setae in proximal half which become one line is distal half; venation as in Fig. 13; linea calva closed posteriorly and interrupted by setae; proximal to linea calva setae hyaline, except brown setae in about anterior third (Fig. 13). Hind wing 4.38× as long as broad; marginal fringe 0.4× wing width. *Relative measurements* (slide, at 100×): mid tibia length, 23; mid basitarsus length, 8; mid tibial spur length, 6.5.

Metasoma (Fig. 12) 1.43× as long as mesosoma (43:30); second valvifer 4.21× as long as third valvula. *Relative measurements* (slide, at 100×): TVII length (width), 22 (19); ovipositor length, 18.25; third valvula length, 3.5. [Ovipositor 0.79× mid tibia length; third valvula 0.43× mid basitarsus length.]

Male: Unknown.

Material examined: Holotype, female (on slide under 4 coverslips, slide No. EH.1715), labelled "INDIA: ANI: Little Andaman, Hut Bay, 28.i.2013 (SN), Coll. K. Veenakumari". (NBAIR; registration No. ICAR/NBAIR/EN.36).

Distribution: India: Andaman and Nicobar Islands.

Etymology: Arabic, *jazirah* = island, and may be taken as a noun in apposition.

Comments: The genus *Coccidencyrtus* Ashmead contains 33 currently valid world species (Noyes, 2014). Of these, seven (possibly eight) species are characterized by the complete or incomplete fusion of the basal three funicle segments (F1–F3). These species are: *C. albiflagellum* (Girault), *C. albitarsus* (Girault), *C. auricornis* (Girault), *C. australis* (Girault), *C. clavatus* (Hayat, Alam and Agarwal), *C. secundus* (Girault), *C. shafeei* (Hayat, Alam and Agarwal), and *C. wallacei* (Girault). Of these species, two species (*C. clavatus* and *C. shafeei*) are from India, and the remaining species are all from Australia.

The new species, *C. jazirah* Hayat, sp. nov., runs to *C. australis* in the key to species given by Noyes and Ren (1987) because of similar colour of the legs, but based on the original description given by Girault (1915: 132) and the key characters given by Noyes and Ren (1987), the new species differs from *C. australis* by the following characters: antennal pedicel less than half the length of funicle; F1–F3 combined 1.75× as long as broad; clava shorter than pedicel and funicle combined. In *C. australis:* pedicel over half the length of funicle; F1–F3 combined a little longer than wide; clava a little longer than pedicel and funicle combined. Details of sculpture of the mesoscutum and scutellum, and relative lengths of the ovipositor, third valvula and mid tibia are not known for Girault's species.

3. *Ooencyrtus zenon* Hayat, sp. nov. (Figs 14–19)

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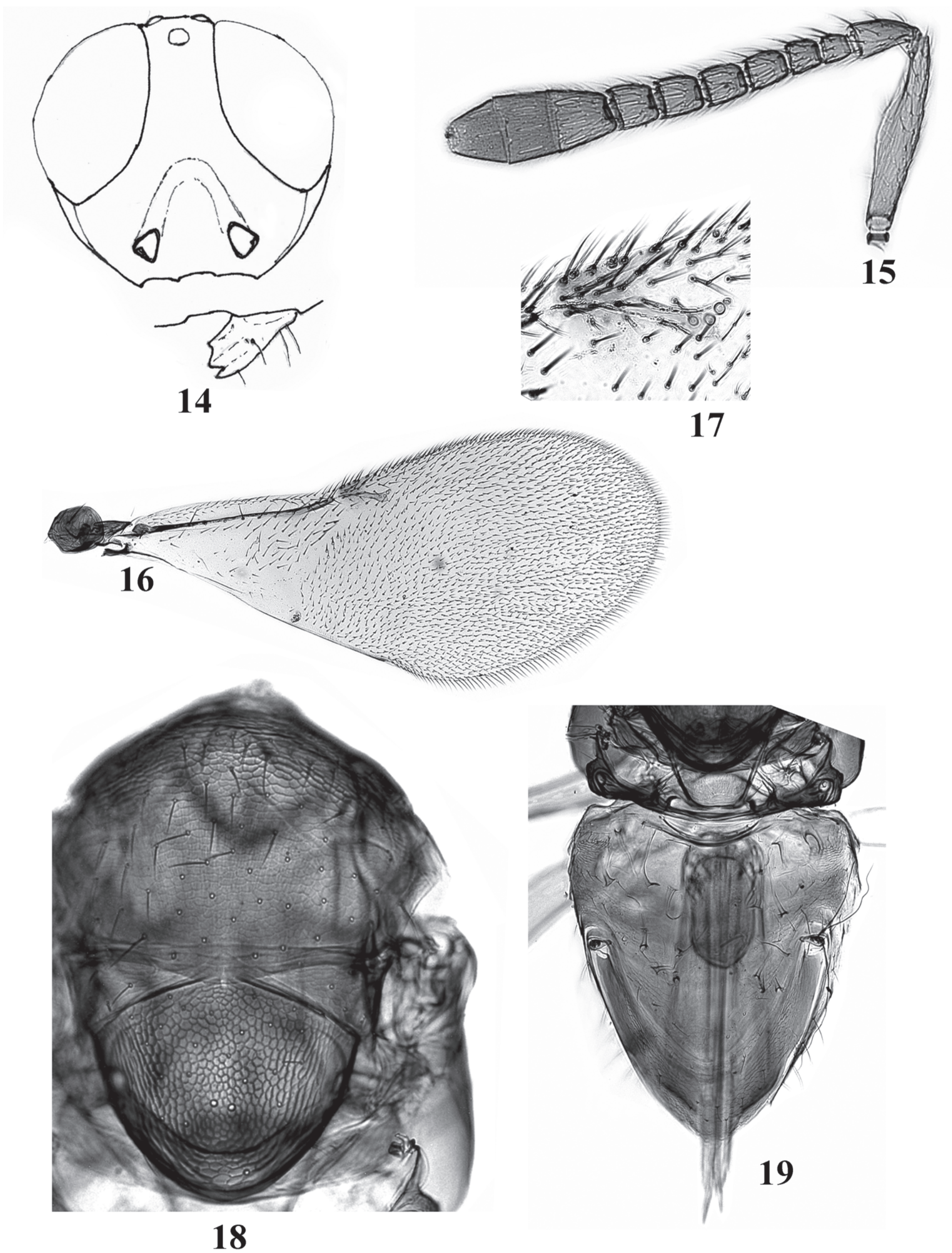
Female

Holotype. Length, 1.0 mm. Head dark brown, with dull violet shine. Antenna with scape pale brownish yellow; pedicel in about basal half brown, apical half pale yellow; funicle segments (F1, F2) brown becoming yellowish brown on F3–F6; clava brown. Mesosoma, including tegula, dark brown; mesoscutum shiny; scutellum with purple shine, sides and posterior part smooth and dull bluish green. Wings hyaline; fore wing below parastigma and submarginal vein with yellowish tinge. Legs, including coxae, pale yellow. Gaster brown; TI, except brown sides, white; exserted part of ovipositor sheaths pale brownish yellow.

Head dorsum 1.73× as broad as long; ocellar triangle with apical angle slightly acute; POL less than OCL (2.5:4); head, in frontal view (Fig. 14), 1.16× as broad as high; frontovertex width 0.22× head width or head width 4.42× as broad as frontovertex width; mouth fossa 1.57× frontovertex width; scrobes shallow, inverted U-shaped with rounded margins; eye large, 2× as long as malar space; frontovertex appears smooth with sparse, long, brown setae; malar space with fine, lineolate sculpture; eye with fine, hyaline setae, each seta longer than a facet diameter. Mandible (Fig. 14) apically slightly narrow, with 2 pointed teeth and a small, slightly



FIGURES 14–18. ***Ooencyrtus zenon*** **Hayat, sp. nov., holotype, female: 14, head frontal view, with mandible enlarged; 15, antenna; 16, fore wing; 17, distal venation of fore wing; 18, thoracic dorsum; 19, metasoma.**

receding truncation. Antenna (Fig. 15) with scape 4.6× as long as broad, and 1.78× as long as frontovertex width; pedicel nearly as long as F1 and F2 combined; funicle segments quadrate (F2, F5, F6) to slightly longer than broad (F1, F3, F4). *Relative measurements* (slide, at 100×): head frontal width, 42; head frontal height, 36; frontovertex width, 9.5; mouth fossa width, 15; eye height, 26; malar space, 13; antennal scape length, 17; pedicel length, 6; funicle length, 22; clava length, 15.

Mesosoma (Fig. 18). Pronotum with raised reticulate sculpture, the cells small and transversely elongate; mesoscutum with polygonal reticulate sculpture, deeper in anterior third and fine in posterior two-thirds; scutellum with raised, polygonal reticulate sculpture, cells small, and deeper than on mesoscutum, lateral fourth with elongate reticulate sculpture, and in apical fourth cells transversely drawn-out; setae brown. Fore wing (Fig. 16) 2.28× as long as broad; postmarginal vein about as long as marginal vein, and 0.7× stigmal vein (Fig. 17); linea calva open posteriorly; basal triangle nearly bare. Hind wing 4.34× as long as broad. Mid tibia 2.79× as long as mid basitarsus, the latter 1.33× as long as mid tibial spur. *Relative measurements* (slide, at 100×): mesosoma length, 48; fore wing length (width), 93.5 (41); hind wing length (width), 63 (14.5); mid tibia length, 33.5; mid basitarsus length, 12; mid tibial spur length, 9.

Metasoma (Fig. 19). *Relative measurements* (slide, at 100×): gaster length, 50; TVII, measured between cercal plates, length (width), 30.5 (30); ovipositor length, 54; third valvula length, 13; exserted part of ovipositor sheaths, 6 [Ovipositor 1.61× as long as mid tibia; third valvula subequal in length to mid basitarsus, and 1.44× as long as mid tibial spur.]

Male: Unknown.

Material examined: Holotype, female (on slide under 4 coverslips, slide No. EH.1733), labelled "INDIA: ANI: South Andaman, Garacharma, 26.i.2013 (YPT), Coll. K. Veenakumari" (NBAIR; registration No. ICAR/NBAIR/EN.37).

Distribution: India: Andaman and Nicobar Islands.

Etymology: The species name is an arbitrary combination of letters, and may be taken as a noun in apposition.

Comments: The genus *Ooencyrtus* Ashmead presently contains 300 world species (Noyes, 2014). This new species is different from all the described species (Noyes, 1985, Neotropical species; Prinsloo, 1987, species from sub-Saharan Africa; Trjapitzin, 1989, Palaearctic species; Huang and Noyes, 1994, Indo-Pacific species; Hayat, 2006, Indian species; Noyes, 2010, Costa Rican species), and does not run to any species in the available keys to *Ooencyrtus* species.

4. *Paraphaenodiscus nesiotes* Hayat, sp. nov. (Figs 20–26)

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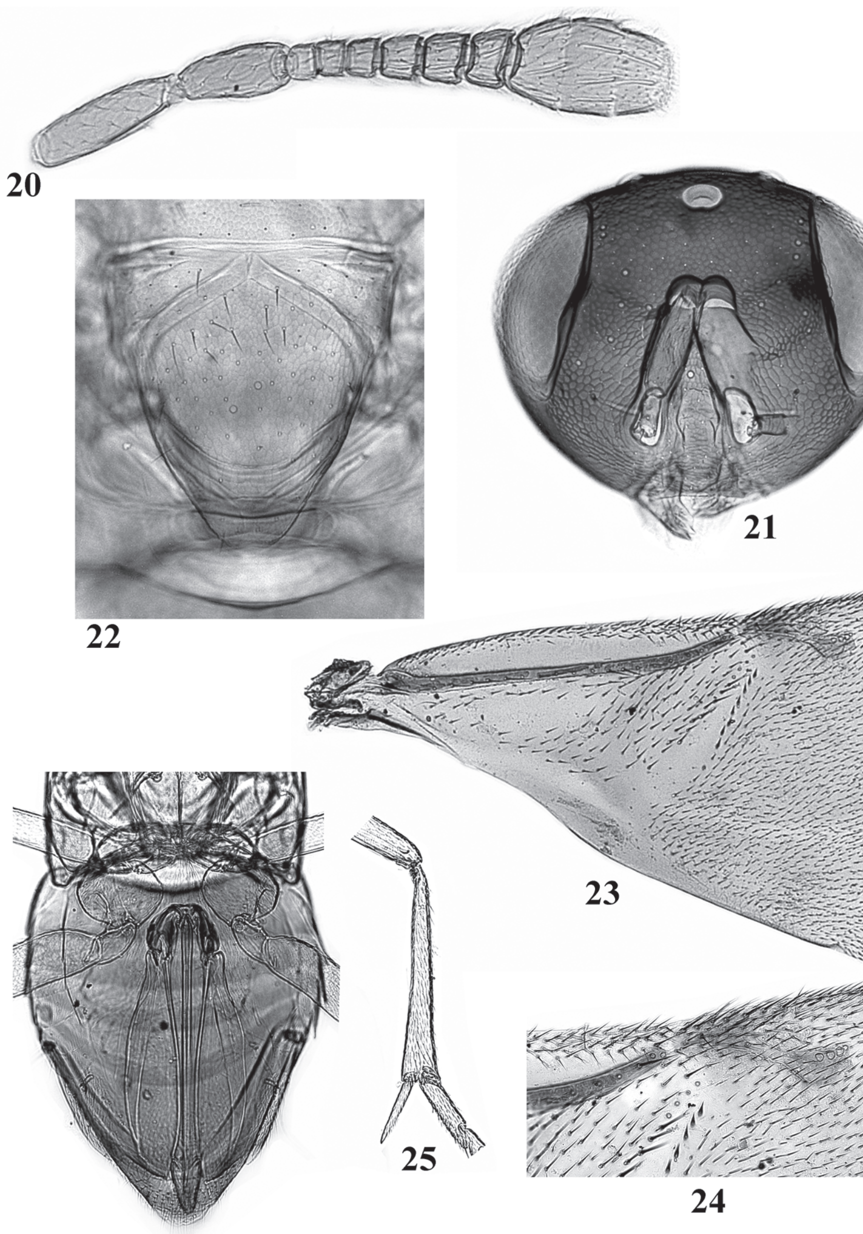


FIGURES 20–26. ***Paraphaenodiscus nesiotes*** **Hayat, sp. nov., holotype, female: 20, antenna; 21, head frontal view; 22, part of mesosoma showing scutellar flange; 23, basal part of fore wing; 24, distal venation of fore wing; 25, mid tibia, basitarsus and spur, at same magnification as Fig. 26; 26, apex of scutellum, propodeum and metasoma.**

Female

Holotype. Length, 1.1 mm. Head dark brown; frontovertex largely with bronzy violet shine. Antenna with scape yellow; pedicel yellow with upper margin brown; flagellum brownish yellow. Mesosoma with visible part of pronotum, mesoscutum, axilla, and scutellum pale brown; tegulae yellow; metanotum and propodeum brown; prepectus and pleurites pale brownish yellow. [On slide, mesosoma appears yellow.] Fore wing, including costal cell, infuscate, the infuscation fading towards apex of disc. Legs, including coxae, pale brownish yellow; mid and hind tibiae, mid tibial spur and all tarsi pale yellow. Gaster brown.

Head, in dorsal view, with occipital margin sharp, and concave between eyes, 2.56× as broad as long; frontovertex broad, 0.54× head width; ocellar triangle with apical angle obtuse; posterior ocellus slightly nearer to occipital margin than to eye margin, POL:OOL:OCL, 8.5:2:1.5; head, in frontal view, 1.2× as broad as high (Fig. 21); scrobes elongate, with upper and lateral margins sharply ridged; interantennal prominence sharply margined (= ridged) and pointed above; antennal torulus with upper margin slightly above lower margin of eye; torulus separated from mouth margin by a distance slightly less than torulus height; eye height 1.6× malar space; frontovertex, face and malar space with regular, polygonal raised reticulate sculpture, the cells very small, and with some scattered minute setigerous punctures; head sparsely setose, setae short and hyaline; eye bare. Antenna (Fig. 20) with scape short, 3.14× as long as broad, 0.5× frontovertex width (11:21.5), and subequal in length to clava; pedicel longer than F1–F3 combined; funicle segments all broader than long, gradually increasing in length and width; clava (collapsed) with apex broadly rounded, slightly shorter than F3–F6 combined. *Relative measurements* (card): head dorsal width, 32; head dorsal length, 12.5; frontovertex width, 17.5. (slide, at 100×): head frontal width, 40; head frontal height, 33; frontovertex width, 21.5; eye height, 20; malar space, 12.5; antennal scape length, 11; pedicel length, 7.5; funicle length, 14; clava length, 11.5.

Mesosoma. Mesoscutum 0.61× scutellum length (including apical flange); scutellar flange distinct, overlapping propodeum medially (Fig. 22); mesoscutum with fine, regular polygonal reticulate sculpture, the cells very small; scutellum with a similar sculpture, the cells slightly larger, but deeper than on mesoscutum, and apically fading; setae pale brown. Fore wing 2.26× as long as broad; marginal vein about 2× as long as broad, shorter than stigmal vein (21:25); postmarginal vein 0.4× marginal vein and 0.36× stigmal vein (Fig. 24); linea calva open; basal triangle with a large bare area, otherwise as in Fig. 23. Mid tibia (Fig. 25) 2.75× as long as mid basitarsus; mid tibial spur slightly shorter than mid basitarsus. *Relative measurements* (card): mesosoma length, 38; pronotum, visible part, length (width), 4 (28); mesoscutum length (width), 13.5 (31); scutellum length, (width), 22 (20). (slide, at 100×): mid tibia length, 33; mid basitarsus length, 12; mid tibial spur length, 10.

Metasoma (Fig. 26) slightly longer than mesosoma (41:38); ovipositor extending from TI of gaster, and not exserted at apex; ovipositor with second valvifer 4.87× as long as third valvula; setae on tergites as follows: TI–TIV, a short line each on each side; TV, a single line, but in posterior third with several setae; TVI, a single line; TVII, numerous setae. *Relative measurements* (slide, at 100×): TVII length (width), measured between cercal plates, 28.5 (35); ovipositor length; 47; third valvula length, 8. [Ovipositor 1.42× as long as mid tibia; third valvula shorter than mid tibial spur.]

Male: Unknown.

Material examined: Holotype, female (on slide under 4 coverslips, slide No. EH.1714), labelled "INDIA: ANI: Little Andaman, Hut Bay, 28.i.2013 (SN), Coll. K. Veenakumari". (NBAIR; registration No. ICAR/NBAIR.EN.38)

Distribution: India: Andaman and Nicobar Islands

Etymology: Greek, *nesiotes* = islander, inhabitant of an island.

Comments: This new species is quite different from all the described species of the genus *Paraphaenodiscus* Girault (Girault, 1915; Prinsloo, 1976; Prinsloo and Mynhardt, 1982; Myartseva, 1980; Singh and Agarwal, 1993; Hayat, 2006; Hayat et al., 2008; Noyes, 2014) in having the following combination of characters: head dark brown in contrast to the yellow to brownish yellow mesosoma; antennal funicle and clava brownish yellow; head with frontovertex broad, 0.54× head width; scrobes deep, elongate and sharply ridged; interantennal prominence sharply ridged, triangularly pointed above. The last three characters are unique for this new species, and not found in any other described species. These characters suggest that the new species may eventually prove to belong to a separate (new) genus, but is here placed in *Paraphaenodiscus* as it agrees in all the other characters with this genus.

The genus *Paraphaenodiscus* is newly recorded from Andaman and Nicobar Islands.

Records of species

1. *Achalcerinys lindus* (Mercet)

Material examined: INDIA: ANI: South Andaman, Garacharma, 9 females, 26.i.2013 (YPT), Coll. K. Veenakumari. (2 females in ZDAMU; 7 females in NBAIR)

2. *Adelencyrtus moderatus* (Howard)

Material examined: INDIA: ANI: South Andaman, Garacharma, 5 females, 26.i.2013 (YPT), Coll. K. Veenakumari; South Andaman, Sippighat, 1 female, 20.i.2013 (SN), Coll. K. Veenakumari. (NBAIR)

3. *Adelencyrtus orissanus* Hayat

Material examined: INDIA: ANI: Garacharma, 1 female, 20.i.2013 (YPT), Coll. K. Veenakumari.

(ZDAMU)

4. ***Amicencyrtus obscurus*** **Hayat [New record of the genus and species from ANI]**

Material examined: INDIA: ANI: South Andaman, Sippighat, 1 female, 20.i.2013 (SN), Coll. K. Veenakumari (NBAIR).

5. ***Anikera andamana*** **Hayat, in Hayat and Veenakumari**

Material examined: INDIA: ANI: Middle Andaman, Chitrakoot, 1 female, 24.i.2013 (SN), Coll. K. Veenakumari; South Andaman, Garacharma, 1 female, 30.i.2013 (SN), Coll. K. Veenakumari; South Andaman, Mt. Harriet, 1 female, 1.ii.2013 (SN), Coll. K. Veenakumari (1 female in ZDAMU; 2 females in NBAIR).

6. ***Arrhenophagoidea andamanica*** **Hayat, in Hayat and Veenakumari**

Material examined: INDIA: ANI: Garacharma, 1 female (on slide No. EH.1713), 30.i.2013 (SN), Coll. K. Veenakumari (NBAIR).

7. ***Cheiloneurus flaccus*** **(Walker)**

Material examined: INDIA: ANI: Middle Andaman, Rangat Bay, 1 female, 23.i.2013 (SN), Coll. K. Veenakumari; Little Andaman, Hut Bay, Waterfalls, 1 female (right fore wing lost; scutellar brush of setae detached), 28.i.2013 (SN), Coll. K. Veenakumari (1 female in ZDAMU; 1 female in NBAIR).

8. ***Cheiloneurus longipennis*** **Fatma and Shafee [New record from ANI]**

Material examined: INDIA: ANI: Middle Andaman, Rangat Bay, 1 female (scutellar brush of setae detached), 23.i.2013 (SN), Coll. K. Veenakumari (ZDAMU).

9. ***Encyrtus aurantii*** **(Geoffroy)**

Material examined: INDIA: ANI: Little Andaman, Harminder Bay, 1 female, 30.i.2013 (SN), Coll. K. Veenakumari (NBAIR).

10. ***Helegonatopus pulchricornis*** **Hayat and Verma [New record of the genus and species from ANI]**

Material examined: INDIA: ANI: Little Andaman, Hut Bay, Waterfalls, 3 males, 28.i.2013 (SN), Coll. K. Veenakumari; Middle Andaman, Rangat Bay, 3 females, 6 males, 23.i.2013 (SN), Coll. K. Veenakumari (NBAIR).

11. ***Indaphycus planus*** **Hayat (Figs 27, 28) [New record of the genus and species from ANI]**

Material examined: INDIA: ANI: Little Andaman, Hut Bay, 1 male (on slide, No. EH.1719), 28.i.2013 (SN), Coll. K. Veenakumari. (ZDAMU).

Comments: This species is known from females from Karnataka (Hayat et al., 2013), Tamil Nadu (Manickavasagam and Rameshkumar, 2011) and Uttar Pradesh (see Hayat, 2006). The male of this species is recorded for the first time, and illustrated (Figs 27, 28). It is very similar to the females, except for the genitalia.

12. *Leptomastix dactylopii* Howard [New record from ANI]

Material examined: INDIA: ANI: Little Andaman, Forest Nursary, 1 female, 30.i.2013, Coll. K. Veenakumari; South Andaman, Garacharma, 1 female (right antenna beyond F5, and left antenna beyond F4, missing), 26.i.2013 (YPT), Coll. K. Veenakumari (NBAIR).

13. *Mahencyrtus ranchiensis* (Fatima and Shafee)

Material examined: INDIA: ANI: South Andaman, Garacharma, 5 females, 26.i.2013 (YPT), Coll. K. Veenakumari (NBAIR).

14. *Manmohanencyrtus hayati* Singh

Material examined: INDIA: ANI: South Andaman, Garacharma, 1 female, 22.ii.2012; 3 males, 22.ii.2012 (SN); 4 males, 26.i.2013 (YPT); 1 female, 30.i.2013 (SN), Coll. K. Veenakumari. (1 female, 2 males, in ZDAMU; 1 female, 5 males, in NBAIR)

15. *Meniscocephalus optabilis* Hayat (Figs 29, 30) [New record from ANI]

Material examined: INDIA: ANI: South Andaman, Garacharma, 1 female (with left antenna and left side wings on a slide, No. EH.1669), 26.i.2013 (YPT), Coll. K. Veenakumari. (ZDAMU)

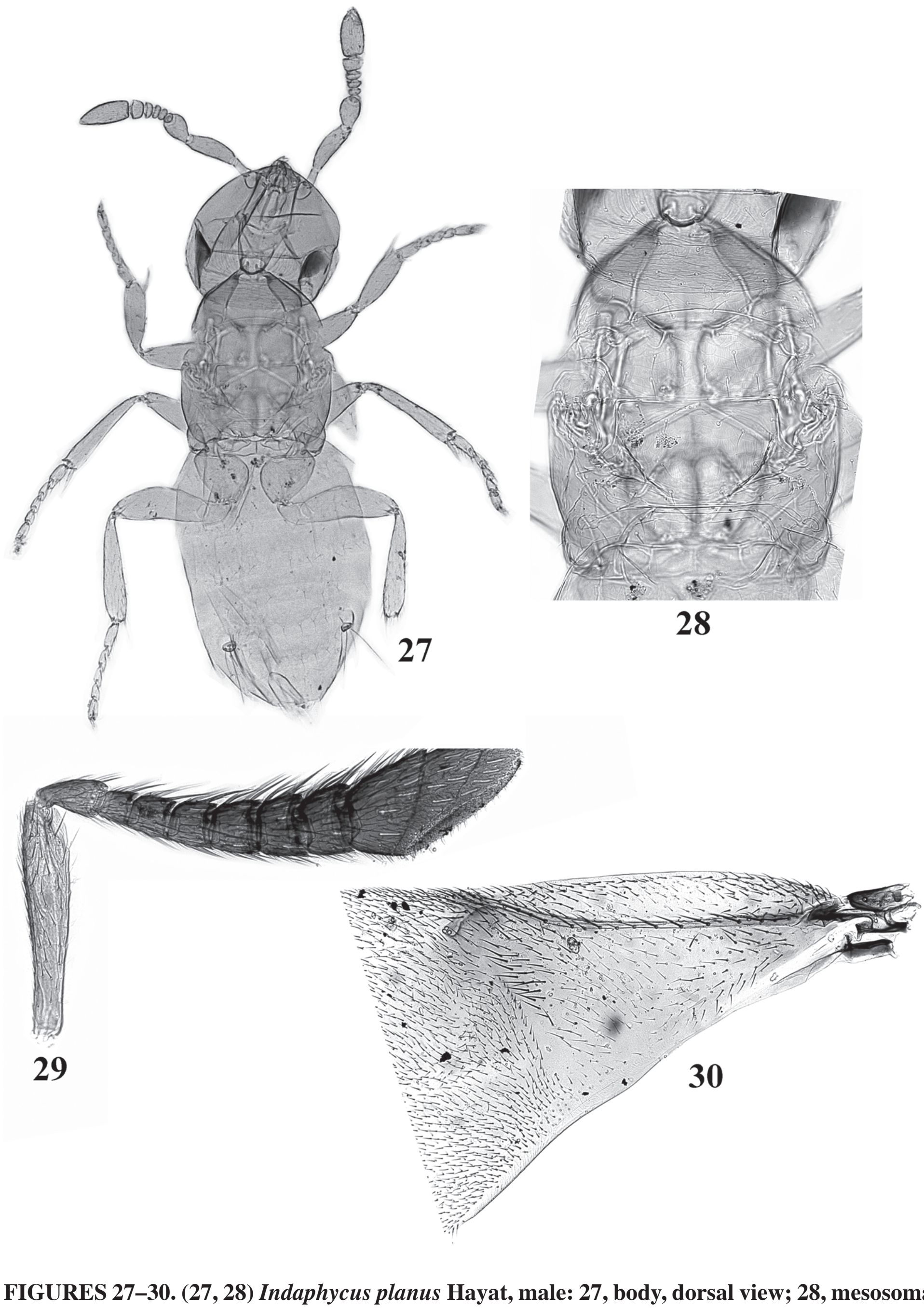
Comments: This species was described by Hayat (2003) from two specimens (holotype and paratype) collected from Kerala. This occurrence of this genus in ANI was earlier reported by Hayat and Veenakumari (2014a).

16. *Neocladia calicutana* (Hayat)

Material examined: INDIA: ANI: South Andaman, Garacharma, 3 females, 30.i.2013 (SN), Coll. K. Veenakumari (1 female, in ZDAMU; 2 females, in NBAIR).

17. *Ooencyrtus guamensis* Fullaway [New record from ANI]

Material examined: INDIA: ANI: Little Andaman, Farm Tikrey, 1 female, 30.i.2013, Coll. K. Veenakumari; South Andaman, Garacharma, 1 female, 22.ii.2012 (SN); 1 female, 26.i.2013 (YPT), Coll. K. Veenakumari (NBAIR).



FIGURES 27–30. (27, 28) *Indaphycus planus* Hayat, male: 27, body, dorsal view; 28, mesosoma. (29, 30) *Meniscocephalus optabilis* Hayat, female: 29, antenna; 30, part of fore wing.

18. *Ooencyrtus papilionis* Ashmead

Material examined: INDIA: ANI: South Andaman, Mile Tilak, 1 female (on slide, No. EH.1705), 22.ii.2012, Coll. K. Veenakumari; South Andaman, Mt. Harriet, 1 female (on slide, No. EH.1735), 1.ii.2013 (SN), Coll. K. Veenakumari (NBAIR; 1 female, slide No.EH.1735, in ZDAMU).

19. *Ooencyrtus utetheisae* (Risbec)

Material examined: INDIA: ANI: Little Andaman, Forest Nursary, 4 females, 29.i.2013 (SN); 1 female, 30.i.2013 (MT), Coll. K. Veenakumari; South Andaman, Sippighat, 3 females (one on slide, No. EH.1734), 20.i.2013 (SN), Coll. K. Veenakumari (NBAIR; 1 female, slide No. EH.1734, in ZDAMU).

20. *Paraclausenia herbicola* Hayat

Material examined: INDIA: ANI: South Andaman, Sippighat, 1 female, 20.i.2013 (SN), Coll. K. Veenakumari; South Andaman, Garacharma, 2 females, 26.i.2013 (YPT), Coll. K. Veenakumari (NBAIR).

21. *Tassonia amaura* Hayat

Material examined: INDIA: ANI: South Andaman, Garacharma, 1 female, 26.i.2013 (YPT), Coll. K. Veenakumari (NBAIR).

22. *Tassonia calunica* Hayat

Material examined: INDIA: ANI: South Andaman, Garacharma, 1 female, 26.i.2013 (YPT), Coll. K. Veenakumari (NBAIR).

23. *Trechnites hairah* Hayat, in Hayat and Veenakumari

Material examined: INDIA: ANI: South Andaman, Chitratapu, 1 male, 22.ii.2012 (SN), Coll. K. Veenakumari; South Andaman, Garacharma, 3 females, 30.i.2013 (SN), Coll. K. Veenakumari; South Andaman, Mt. Harriet, 1 female, 1.ii.2013 (SN), Coll. K. Veenakumari; Little Andaman, Harminder Bay, 1 female, 1 male, 30.i.2013 (SN), Coll. K. Veenakumari (1 female, in ZDAMU; remaining specimens in NBAIR).

LIST OF ENCYRTIDAE FROM ANDAMAN AND NICOBAR ISLANDS

The reference to the first record of a species from ANI is given in square brackets. For species described on material from ANI (holotypes/paratypes/additional material included along with type material) only the year is enclosed in square brackets.

1. *Achalcerinys lindus* (Mercet) [Hayat and Veenakumari, 2013]
2. *Adelencyrtus bimaculatus* Alam [Hayat and Basha, 2001]
3. *Adelencyrtus coxalis* Hayat et al. [Manickavasagam and Rameshkumar, 2013]
4. *Adelencyrtus moderatus* (Howard) [Hayat and Basha, 2001]
5. *Adelencyrtus orissanus* Hayat [Manickavasagam and Rameshkumar, 2013]
6. *Aenasius advena* Compere [Noyes and Ren, 1995]
7. *Ageniaspis montanus* Hayat, **sp. nov.** [**present paper**]
8. *Amicencyrtus obscurus* Hayat [**present record**]
9. *Anagyrus dactylopii* (Howard) [Hayat and Basha, 2001]
10. *Anagyrus diversicornis* (Howard) [Gupta and Joshi, 2013]
11. *Anagyrus gracilis* (Hayat) [Hayat and Basha, 2001]
12. *Anagyrus kamali* Moursi [Manickavasagam and Rameshkumar, 2013]
13. *Anagyrus levis* Noyes and Hayat [Hayat and Veenakumari, 2014a]
14. *Anagyrus mirzai* Agarwal and Alam [Hayat and Singh, 1999]
15. *Anagyrus ranchiensis* Shamim and Shafee [Hayat and Veenakumari, 2014a]
16. *Anagyrus rugas* Noyes and Hayat [Hayat and Veenakumari, 2014a]
17. *Anagyrus shahidi* Hayat [Manickavasagam and Rameshkumar, 2013]
18. *Anagyrus subflaviceps* (Girault) [Hayat and Singh, 1999]
19. *Anagyrus thailandicus* (Myartseva) [Manickavasagam and Rameshkumar, 2013]
20. *Anagyrus tricolor* (Girault) [Hayat and Veenakumari, 2013]
21. *Anagyrus umairi* Noyes and Hayat [Hayat and Singh, 1999]
22. *Anicetus annulatus* Timberlake [Hayat and Veenakumari, 2013]
23. *Anikera andamana* Hayat, in Hayat and Veenakumari [2013]
24. *Anomalicornia tenuicornis* Mercet [Manickavasagam and Rameshkumar, 2013]
25. *Aphycus sapporoensis* (Compere and Annecke) [Manickavasagam and Rameshkumar, 2013]
26. *Apoleptomastix bicoloricornis* (Girault) [Hayat and Veenakumari, 2013]
27. *Arrhenophagoidea andamanica* Hayat, in Hayat and Veenakumari [2014b]
28. *Blepyrus insularis* (Cameron) [Manickavasagam and Rameshkumar, 2013]
29. *Callipteroma sexguttata* Motschulsky [Manickavasagam and Rameshkumar, 2013]

30. *Callipteroma testacea* Motschulsky [Hayat and Veenakumari, 2013]
31. *Cheiloneuromyia javensis* Girault [Hayat and Singh, 2002]
32. *Cheiloneurus bangalorensis* (Subba Rao) [Hayat and Basha, 2001]
33. *Cheiloneurus flaccus* (Walker) [Hayat and Veenakumari, 2014a]
34. *Cheiloneurus longipennis* Fatma and Shafee [**present record**]
35. *Cheiloneurus parvus* (Hayat) [Hayat and Veenakumari, 2014a]
36. *Cheiloneurus quadricolor* (Girault) [Hayat and Singh, 1999]
37. *Cheiloneurus saissetiae* Noyes and Chua [As *C. insulus* Kaul and Agarwal, 1986; synonymy by Anis and Hayat, 2002]
38. *Coagerus bouceki* Noyes and Hayat [Hayat and Veenakumari, 2014a]
39. *Coccidencyrtus clavatus* (Hayat et al.) [Hayat and Basha, 2001]
40. *Coccidencyrtus jazirah* Hayat, **sp. nov.** [**present paper**]
41. *Coccidencyrtus shafeei* (Hayat et al.) [Manickavasagam and Rameshkumar, 2013]
42. *Coelopencyrtus krishnamurtii* (Mahdihassan) [Hayat and Basha, 2001]
43. *Diversinervus cervantesi* (Girault) [As *Phasmencyrtus indicus* Kaul and Agarwal, 1986; synonym of *D. cervantesi* by Hayat, 1989]
44. *Diversinervus elegans* Silvestri [Hayat and Veenakumari, 2013]
45. *Encyrtus aurantii* (Geoffroy) [Hayat and Singh, 1999]
46. *Epitetracnemus intersectus* (Fonscolombe) [Hayat, 2006]
47. *Exoristobia columbi* (Girault) [Hayat and Veenakumari, 2014a]
48. *Helegonatopus pulchricornis* Hayat and Verma [**present record**]
49. *Indaphycus planus* Hayat [**present record**]
50. *Lakshaphagus fusiscapus* (Agarwal) [Gupta and Joshi, 2013]
51. *Leptomastix dactylopii* Howard [**present record**]
52. *Leptomastix nigrocincta* Risbec [Hayat and Singh, 1999]
53. *Leptomastix tsukumiensis* Tachikawa [Hayat and Veenakumari, 2013]
54. *Leurocerus ovivorus* Crawford [Veenakumari et al., 1997]
55. *Mahencyrtus assamensis* Singh and Agarwal [Hayat and Veenakumari, 2014a]
56. *Mahencyrtus ranchiensis* (Fatima and Shafee) [Manickavasagam and Rameshkumar, 2013]
57. *Manmohanencyrtus hayati* Singh [1995]

58. *Meniscocephalus optabilis* Hayat [**present record**]
59. *Microterys indicus* Subba Rao [Hayat and Veenakumari, 2014a]
60. *Neocladia calicutana* (Hayat) [Hayat and Veenakumari, 2014a]
61. *Neocladia trifasciata* Singh and Agarwal [1993]
62. *Neodusmetia sangwani* (Subba Rao) [Hayat and Basha, 2001]
63. *Ooencyrtus guamensis* Fullaway [**present record**]
64. *Ooencyrtus insulanus* Hayat and Veenakumari [2014a]
65. *Ooencyrtus lucens* Huang and Noyes [1994]
66. *Ooencyrtus papilionis* Ashmead [Manickavasagam and Rameshkumar, 2013]
67. *Ooencyrtus utetheisae* (Risbec) [Manickavasagam and Rameshkumar, 2013]
68. *Ooencyrtus zenon* Hayat, **sp. nov.** [**present paper**]
69. *Paraclausenia herbicola* Hayat [Manickavasagam and Rameshkumar, 2013]
70. *Paraphaenodiscus nesiotes* Hayat, **sp. nov.** [**present paper**]
71. *Paratetracnemoidea insulana* Hayat and Singh [2002]
72. *Prochiloneurus pulchellus* Silvestri [Hayat and Veenakumari, 2013]
73. *Prochiloneurus testaceus* (Agarwal) [Hayat and Singh, 1999]
74. *Protyndarichoides indicus* Singh and Agarwal [Manickavasagam and Rameshkumar, 2013]
75. *Rhopus nigroclavatus* (Ashmead) [Hayat and Veenakumari, 2013]
76. *Saucrencyrtus insulanus* Hayat and Singh [2002]
77. *Syrphophagus hofferi* (Hayat) [Hayat and Veenakumari, 2013]
78. *Tassonia amaura* Hayat [Hayat and Veenakumari, 2013]
79. *Tassonia calunica* Hayat [2003]
80. *Tassonia gloriae* Girault [Hayat and Veenakumari, 2013]
81. *Trechnites hairah* Hayat, in Hayat and Veenakumari [2013]
82. *Zaomma lambinus* (Walker) [Hayat and Basha, 2001]

In addition to the above species, the following genera, without included species, are recorded:

Manickavasagam and Rameshkumar (2013): *Metaphycus* Mercet, *Neastymachus* Girault, *Rhytidothorax* Ashmead.

Hayat and Veenakumari (2014a): *Arrhenophagus* Aurivillius, *Tachinaephagus* Ashmead.

ACKNOWLEDGEMENTS

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Low cost cage for rearing of American serpentine leaf miner, *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae)

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ABSTRACT: A simple low cost cage for rearing of American serpentine leaf miner, *Liriomyza trifolii* (Burgess) was designed, providing better aeration and penetration of light. This cage is very useful for multiplying insects during off season. ©2014 Association for Advancement of Entomology

KEY WORDS: *Liriomyza trifolii*, Agromyzidae, low cost rearing cage

Liriomyza trifolii (Burgess) (Diptera: Agromyzidae), commonly known as the American serpentine leaf miner, is a serious pest of vegetable and ornamental plants. It is a native of Florida in United States of America and Carribean Islands (Spencer, 1973). This insect was introduced to India in 1990's. Since then the pest distribution has been reported on 79 species of crop plants (Srinivasan *et al*., 1995).

The incidence of *L. trifolii* varied in different seasons. The infestation of *L. trifolii* occured from October to May in Kerala with maximum infestation in the months of January, February and March and (KHDP, 1998), whereas Karnataka the peak incidence was reported to during May to September (IIHR, 1998) and very low during the rainy season. In order to have *L. trifolii* for laboratory studies, a low cost rearing cage was fabricated.

Cowpea (*Vigna unguiculata*) seeds (var. Anaswara) were sown in plastic pots of height 6 cm and diameter 6.5 cm. When the seedlings were nine days old, they were covered with polythene covers with pin holes. Adults of *L. trifolii* were released in the ratio of 2 o: 1 o into the covers and these were tied tightly to the plastic pot to prevent the escape of adult flies. The pinholes in the polythene covers facilitated aeration and prevention of moisture accumulation inside the polythene covers. Female flies oviposited on the leaves.

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In order to get more larvae, the seedlings were changed once in two days. The development of mines was observed. The pre pupae emerged from the mines in five to six days and pupated inside the polythene covers within few hours. The pupae were collected with the help of camel hair brush and placed in small glass vials, and kept at room temperature till the adult emergence. The emerged adults were again released to cowpea seedlings to maintain the laboratory culture of the insect. Cotton soaked in honey solution mixed with Vitamin E was given as food for the adults. Cotton pieces soaked in this solution were placed inside the polythene bags.

A rearing cage of size 40×30×30 cm^3 was fabricated with cardboard, polythene sheet and muslin cloth to rear *L. trifolii* during the off season when population of leaf miner adults was very low in the field. The front side of cage was provided with a circular opening of 17 cm diameter and a muslin cloth sleeve was stitched and pasted around the opening. This opening was used for handling the insects and plants inside the cage. The distal end of cloth sleeve was kept closed while not in use. A window of size 22×13 cm^2 was cut on the sides of the cage and was closed by fixing muslin cloth. Two rectangular windows of 14 cm length and 12.5 cm breadth were cut on the back side and top of the cage were covered with plastic sheet and perforated for aeration and also for the entry of sunlight. The joints of the cage were carefully sealed from inside. Similar cage were used for parasitization studies for leaf miner by Bordat *et al*. (1995).

Cowpea seeds (var. Anaswara) were sown in disposable cups of 6 cm height and 6.5 cm diameter. Three fourth of the cup was filled with potting mixture prepared in the ratio 1:1:1 with soil, sand and cowdung. Three seeds were sown in each cup. Nine days old seedlings were used for the culturing of *L. trifolii*. After the adult emergence, the flies were separated as males and females based on the absence or presence of ovipositor at the tip of abdomen.

Ten to fifteen pairs of newly emerged adults were released in to the rearing cage for oviposition. Steps in the mass rearing of *L. trifolii* are given in Plate 1.

Maximum number of larval mines observed from an infested plant was 30 and a total of 520 maggots were obtained within four days from 45 seedlings after two days of release of 10 to 15 pairs of adult flies from a single cage. One adult female lays a maximum of 48 to 50 eggs during its life span and the peak egg laying was noticed on the 2^{nd} day after mating with an average of 19.6 eggs closely followed by the third day (Smitha, 2003). Multiple mating has also been reported.

The design of this rearing cage is very simple, providing better aeration and penetration of light. This cage is very useful for multiplying insects during off season. More number of plants can be infested with a few adults. More trials are needed to standardize the optimum number of adults to get maximum number of progenies.

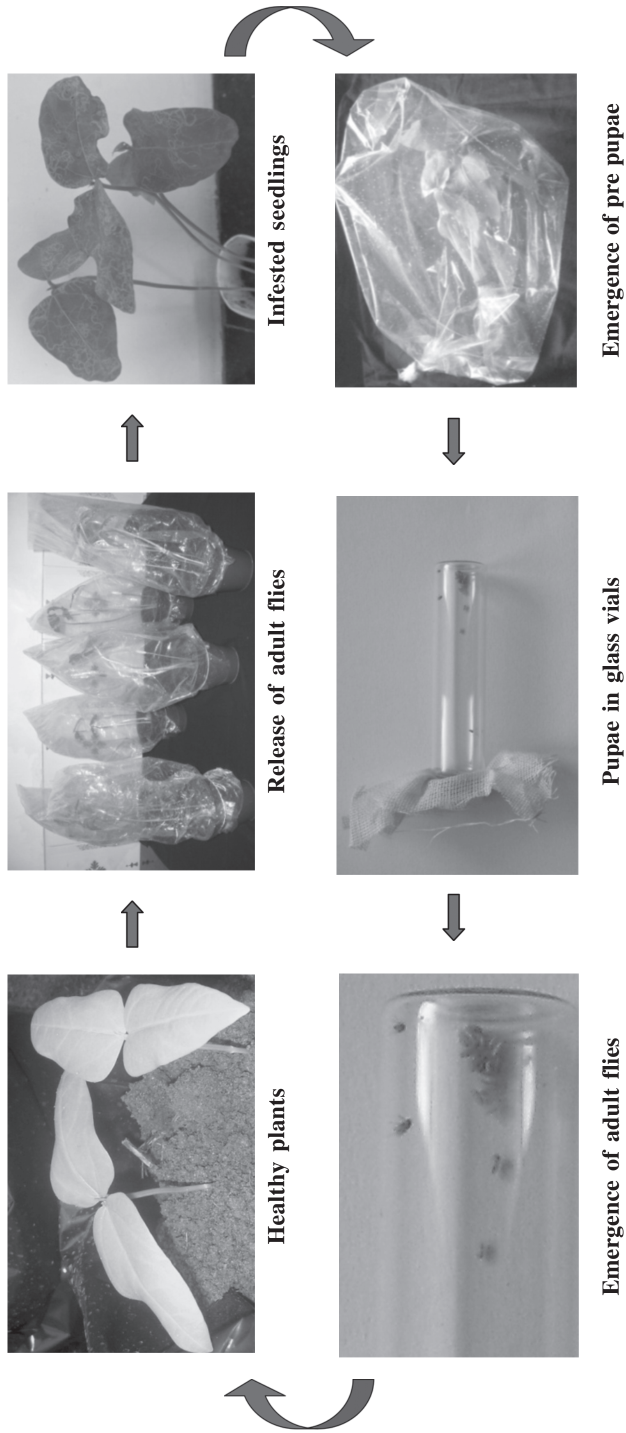

Plate 1. Steps in the mass rearing of *Liriomyza trifolii*

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Report of banana pseudostem weevil (*Odoiporus longicollis* Olivier) infestation on leaf petiole

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ABSTRACT: During our survey a different site of infestation by *Odoiporus longicollis* was observed in 'Nendran' cultivar plots at Konny, Pathanamthitta District, Kerala. Feeding and exit holes of the grubs were observed on leaf petioles. Absence of continuous grub feeding channels from leaf sheath base to petiole suggests direct oviposition on the petiole. ©2014 Association for Advancement of Entomology

Keywords: banana pseudostem weevil, *Odoiporus longicollis,* infestation on leaf petiole.

In India, banana (*Musa* sp.) enjoys top rank among the fruit crops in terms of production. Globally, India is the largest producer of banana (NHB, 2013). The crop, with its diversified regional cultivars, is cultivated throughout the country. Four hundred and seventy species of insects and mites were reported globally in banana as major and minor pests (Ostmark,1974). Among the plethora of pests, pseudostem weevil (*Odoiporus longicollis* Olivier (Coleoptera: Curculionidae)) is a major pest of banana. The pest had been reported from Delhi (Batra,1952), Kathmandu Valley (Singh,1966), Uttar Pradesh (Shukla and Kumar,1969), Bihar (Tiwary,1971) West Bengal (Dutt and Maiti, 1972), Assam (Isahaque, 1978), Kerala (Visalakshi *et al*., 1989), Tamil Nadu (Padmanaban and Sundararaju, 1999), Karnataka (Jayanthi and Verghese, 1999) and Jammu and Kashmir (Azam *et al*., 2010).

In severely infested plantations, more than 20 per cent plants do not flower if advanced pre flowering stage of the crop is attacked. It is also estimated that 10-90 per cent yield loss may be caused by the stem weevil depending on growth stage and management efficiency (Padmanaban and Sathiamoorthy, 2001).

Adult female weevil lays eggs inside the leaf sheath singly. Emerging grubs are apodous, soft

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with reddish brown head and cream coloured body. It passes through five instars before pupation. Pupa is exarate and occluded in a cocoon made out of banana fibers Total Life cycle of the pest may vary from 53 to 100 days (Dutt and Maiti, 1972; Anitha, 2000 and Thippaiah *et al*., 2011).

O.longicollis usually prefer pseudostem of banana having five month or above age for oviposition (Padmanaban and Sathiamoorthy, 2001). The adult weevils have been found surviving on banana stumps (Padmanaban and Kandasamy, 2003). Adult weevils distinguish acceptable host plants aided by the presence of sensory chemoreceptors on the antennae, mouthparts, tibia etc. (Nahif *et al*., 2003).

During our survey a different site of infestation by *O.longicollis* was observed in 'Nendran' cultivar plots at Konny, Pathanamthitta District, Kerala. Feeding and exit holes of the grubs were observed on leaf petioles. Holes were noticed on petiole from 5cm above the leaf axil. Pupae and grubs were found inside the infested petiole. Symptoms were noticed on one or two lower old leaves. Plants with infested petioles also had holes and ooze out on pseudo stem indicating infestation at lower plant parts. Petioles when opened, yielded 1-2 grubs (average 0.833grubs/petiole) and 0-1 pupa. One adult weevil was also recorded from inside the petiole. Tunneling and tissue damage by feeding of developing grubs were observed in these petioles. Infested leaves became pale green in colour, sometimes broken off at weaker point with holes near to petiole base. Infestation was found limited up to 30-20 cm on petiole from the leaf axil. Absence of continuous grub feeding channels from leaf sheath base to petiole suggests direct oviposition on the petiole. Earlier, weevil attack was observed on peduncle (Padmanaban *et al*., 2001).

Adopting plant protection measures during early stages of infestation is the key in managing this pest economically. But, infestation on upper parts makes early identification of the pest very difficult and many times it may not be get noticed. This new site of infestation can be considered as the survival strategy adopted by the insect to avoid pesticide application on pseudostem and leaf axils. Current pest management practices comprise of using contact insecticides on pseudostem and leaf axils (Kerala Agricultural University, 2009) will not reach the grubs harbouring leaf petiole and hence new tactics has to be formulated to tackle the hitherto unknown infestation site.

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Studies on the extent of damage caused by *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae) on six vegetable crops

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ABSTRACT: A survey was conducted to study the incidence and extent of damage caused by American serpentine leaf miner, *Liriomyza trifolii* on six vegetable crops, using an infestation index and score for the intensity of infestation in a 0 – 4 scale based on the infested area on each leaf. Among the six crops surveyed maximum infestation index was observed in ash gourd (55%) followed by cowpea (45%). The older leaves were preferred more than the younger leaves. The infestation (25%) was minimum in pumpkin and bitter gourd.©2014 Association for Advancement of Entomology

KEY WORDS: *Liriomyza trifolii,* incidence and extent of damage, vegetable crops.

The leaf miners, *Liriomyza* spp. are economically important phytophagous pests of several vegetable crops coming under the family Agromyzidae (Diptera). Six species of *Liriomyza* are reported as polyphagous pests (Morgan *et al*., 2000; Linden, 2004).

The American serpentine leaf miner, *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae) is a serious pest of vegetable and ornamental plants. The pest surveillance conducted in Kerala by KHDP (1998) and Smitha (2003) revealed severe incidence of *L. trifolii* on cowpea, ash gourd, bitter gourd and tomato and higher incidence of this pest was reported during the months of January to March. The damage is caused by the maggots which are leaf miners, feeding on the mesophyll tissues leaving the epidermis intact, resulting in serpentine mines on the upper leaf surface. Heavy infestation causes desiccation and drying of leaves (Chandler and Thomas, 1983). The wide host range, short life cycle and faster development of resistance to insecticides make the management of *L. trifolii* very difficult.

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A survey was conducted at the Department of Agricultural Entomology, College of Horticulture, Kerala Agricultural University, Vellanikkara to study the extent of damage caused by *L. trifolii* from six vegetable crops, namely, cowpea (*Vigna unguiculata* (L.)), ash gourd (*Benincasa hispida* Thunb.), snake gourd (*Trichosanthes cucumerina* L.), bitter gourd (*Momordica charantia* L.), watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai)) and pumpkin (*Cucurbita moschata* Duchesne) grown in Madakkathara and Vellanikkara of Thrissur district to estimate the extent of infestation caused by *L. trifolii*. Ten infested plants from each crop were randomly selected in the crop fields. From each plant, 15 leaves were selected at random for taking observations on damage.

Scoring for the intensity of infestation was done in a 0 – 4 scale (Table 1) based on the infested area present on each leaf.

Table 1. Scoring for *Liriomyza trifolii* infestation on leaf

Per cent leaf area infested	Score	Infestation intensity
0	0	No infestation
1 - 15	1	Low infestation
16 - 30	2	Medium infestation
31 - 50	3	High infestation
>51	4	Severe infestation

The infestation index was also worked out for each crop surveyed as given below (Wheeler, 1969).

$$\text{Infestation index} = \frac{\text{Sum of all scores}}{\text{Number of scores} \times \text{Maximum score}} \times 100$$

The intensity of infestation varied in different crops (Table 2). Among the six crops surveyed from two locations of Thrissur district, namely, Madakkathara and Vellanikkara, the highest infestation index was observed in ash gourd (55%) followed by cowpea (45%). The older leaves were preferred more than the younger leaves. The lowest infestation (25%) was observed for pumpkin and bitter gourd.

Ash gourd, cowpea, snake gourd and watermelon were highly preferred by *L. trifolii*. This was in agreement with Smitha (2003) who reported severe infestation of leaf miner on cowpea, ash gourd and pumpkin. Pest surveillance studies conducted by Kerala Horticultural

Table 2. Severity of damage caused by *Liriomyza trifolii* to different crops

Sl. No.	Crops	Infestation index (%)
1	Ash gourd	55.00
2	Cowpea	45.00
3	Snake gourd	42.50
4	Water melon	35.00
5	Pumpkin	25.00
6	Bitter gourd	25.00

Development Programme also showed severe infestation of *L. trifolii* on the above mentioned crops (KHDP, 1998). Reghunath and Gokulapalan (1996) gave an account of the severe infestation of *L. trifolii* in cowpea, tomato and cucurbits in Kerala. Reji (2001) reported the highest incidence of *L. trifolii* during summer season with mean infestation index being 67.63 per cent.

Ash gourd was observed as the highly preferred crop. This corroborates with the finding of Smitha (2003) who also reported the high susceptibility of ash gourd among cucurbits to *L. trifolii*. The bottom leaves were damaged more than upper leaves by the larval stages of *L. trifolii*. The cotyledons were damaged more. The tender leaves were free from infestation. Higher sugar and nitrogen content of the cotyledons would enhance the infestation by *L. trifolii*. According to Ananthakrishnan (1992) sugar acted as feeding stimulants and larvae fed more voraciously on plant parts containing highest concentration of sugars. The chlorophyll content was also higher in cotyledons (Terman, 1977). Feeding activity and fecundity was also reported to be higher with increase in nitrogen content of leaf (Mikenberg and Ottenheim, 1990).

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