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ENTOMON

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Note from the Chief Editor

Dear Entomologists,

Wishing a very happy new year!

This is to update you on ENTOMON.

Publication of the journal is progressing as per schedule by the Association for Advancement of Entomology functioning out of the Department of Agricultural Entomology, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram, Kerala 695522, India. This could be achieved owing to the continuous support and cooperation of research entomologists from India and abroad. The new format of ENTOMON has gained wide acceptance our stakeholders.

After a long gap, ENTOMON regained the National Academy of Agricultural Sciences (NAAS) score in 2015.The NAAS rating of the journal has gone up from 4.12 in 2015 to 4.42 in 2019.

ENTOMON is now included in the full text repository of the Centre for Agriculture and Bioscience International (CABI), which ensures preservation and easy access of articles published in ENTOMON. This is a valuable way of promoting ENTOMON and its research publications amongst the global users.

ENTOMON is listed in worldcat (https://www.worldcat.org) and the Indian Citation Index Journals List (https://www.jbrec.edu.in/IndianCitationIndexJournals.pdf; the serial number of ENTOMON is 496).

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We have iniated Digital Object Identifier (DOI) to each article with effect from December 2018 issue of the Journal. The efforts taken by Professor K Madhavan Nair, our web site Administrator needs special appreciation.

It is appropriate to mention here that this could be achieved by the relentless and untiring yet voluntary efforts of the office bearers of AAE and the members of the Editorial Board of ENTOMON.

ENTOMON extends its gratitude to the contributors, peer reviewers and institutions for their continued support.

GREEN TECHNOLOGIES THAT SAY 'YES' TO PRESERVATION OF BENEFICIAL INSECTS AND TAKES CARE OF OUR PRECIOUS ECOLOGICAL RESOURCES IS A WISE SOLUTION TO ENTOMOLOGICAL CHALLENGES

Dr M.S. Palaniswami

Chief Editor

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SHORT COMMUNICATION

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Distribution and habitat characteristics of the Troidine butterfly community in the Western Ghats, a biodiversity hotspot in India

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ABSTRACT: Investigation on the distribution patterns and habitat requirements of the butterfly tribe, Troidini was carried out in undisturbed forest habitats and disturbed, human-modiûed habitats in the Western Ghats, a biodiversity hotspot in south India. Compared various ecological and biological traits of the four species of this group which included a CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) listed species, *Troides minos* Cramer, an endemic species *Pachliopta pandiyana* Moore, a protected species, *Pachliopta hector* Fabricius and *Pachilopta aristolochiae* Linnaeus. Comparisons were based on transect counts conducted at 66 transects in 22 locations covering six types of habitat systems with a gradient of disturbance and management regimes during 2009 and 2010. Results indicated that *P. aristolochiae* was the most widely distributed species occurring in 90% of the transects sampled and *P. pandiyana* had a restricted distribution (36 %), while both *P. hector* and *T. minos* were observed in 73% of the transects. Sampling of the juveniles on the six species of host plants in the various habitats provided insights into host plant partitioning between these species in the different habitats. Life history traits and morphological characteristics of adult troidines, larval host plant characteristics and habitat characteristics were evaluated and characterized.

KEY WORDS: Troidine butterflies, biological traits, Western Ghats, resource use, disturbance gradient

INTRODUCTION

The most rampant human exploitation of the environment in most parts of the world and especially in the tropics is the destruction and fragmentation of native vegetation. Although environmental disturbance affects the diversity and structure of ecological communities (Southwood, 1977; Spitzer *et al*., 1993; Huston, 1994), the presence of the diverse biota in complex ecosystems ensures higher stability and efficiency due to greater energy flow and nutrient cycling (Vitousek and Hooper, 1993; Tilman, 1997; Hooper *et al*., 2005). Human disturbance and habitat fragmentation in natural ecosystems as well as the effects of these impacts on the biota especially butterflies is well documented (Wood and Gillman, 1998; Steffan-Dewenter and Tscharntke, 2000; Ghazoul, 2002; Koh, 2007; Saikia, 2014). However, most studies are based on temperate butterflies (Blair and Launer, 1997; Kitahara and Sei, 2001; Krauss *et*

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al., 2003; Hogsden and Hutchinson, 2004) while tropical species have received less attention.

The Indian region includes parts of four hotspots (Western Ghats and Sri Lanka, Himalaya, Indo-Burma and Sundaland) out of the 35 global biodiversity hotspots (Mittermeier *et al*., 2011). The Western Ghats situated in south India like most biodiversity hotspots occurs in an area of high human density and rapid population growth (Cincotta *et al*., 2000). Currently only 9 million km^2 remain out of the approximately 16 million km^2 of original tropical rainforests worldwide (Whitmore, 1997; MEA, 2005). The last few decades have witnessed a drastic and rapid disappearance of the South East Asian tropical rainforests (Sodhi *et al*., 2004). Similarly, in the Western Ghats /Sri Lanka hotspot, primary forests have been decimated from the original extent of 182,500 km^2 to a meagre 12,450 km^2 **(Myers *et al*., 2000)**. Although the Kerala part of the Western Ghats has an established network of protected areas and managed forests under administrative control of the State Forest Department, most ecosystems are under strong anthropogenic pressure. Timber felling, extraction of firewood/ fodder and non-wood forest produce, livestock grazing and fire are the most proximate threats to biodiversity in this region.

The tribe Troidini of the family Papilionidae boasts of some of the most spectacular butterflies and consists of about 138 species coming under two subtribes, namely Battina having one genus and Battus Scopoli and Troidina containing the remaining genera (Munroe and Elhrich, 1960; Munroe, 1961; Hancock, 1983; Miller, 1987). This tribe contains many endemic genera and has a disjunct distribution. Two genera *Pachliopta* Reakirt and *Troides* Hubner are found in the Western Ghats region. The former genus has three species *Pachliopta hector* Fabricius, *P. aristolochiae* Linnaeus, *P. pandiyana* Moore and the latter a single species *Troides minos* Cramer. The larvae of this tribe feed exclusively on plants in the family Aristolochiaceae which contain toxic secondary chemicals which are in turn sequestered for defense against predators (Rothschild, 1972; Feeny, 1991; Silva -Brandão *et al*, 2005).

Due to their high sensitivity and swift responses to local temperature, humidity, rainfall and other parameters, butterflies are touted as the most appropriate indicators of environmental variations resulting from habitat disturbance and modification (Kremen, 1992). Different species have different habitat – linked ecological attributes such as life history traits, mobility and resource utilization. Therefore, whether a species can survive in a modified habitat is dictated by how it perceives the altered landscape vis-a-vis these crucial factors. Sawarkar (2005) observed that in the Indian context, the lack of baseline assessments of species and habitats across the various administrative units greatly impedes the integration of biodiversity and social issues in the management of protected areas. Hence attempts to detect patterns of change in structure and diversity of butterfly communities in response to human interference will give fresh insights and help to initiate the necessary conservation efforts.

MATERIALS AND METHODS

Study sites

For monitoring the butterfly species, 66 transects in 22 locations were selected along the Western Ghats covering six types of habitat systems with a gradient of disturbance and management regimes. Three habitats were relatively undisturbed habitats and the other three disturbed, man modified habitats (Fig. 1). The undisturbed habitats included three types of protected areas namely: i) national parks and biosphere reserves which are high priority conservation areas with minimum anthropogenic impacts, ii) wildlife sanctuaries which are protected conservation areas with restricted and sustainable extraction of non wood forest produce and iii) reserve forests which are managed forests with anthropogenic activities mainly timber felling and under the supervision of the State Forest Department. The disturbed habitats included three types of human impacted areas namely: i) reservoir/ dams which are areas located in the vicinity of reservoirs open to the public for sightseeing and tourism, ii) plantations which are privately owned, intensively managed agriculture systems with monoculture/polyculture crop management regimes

and iii) gardens and parks which are public recreational areas with artificially recreated and managed landscapes/ vegetation. The habitat systems/ management types sampled in each location during January 2009 to December 2010 are given in the Table 1.

Butterfly sampling and characterization

Survey method: Butterflies in the selected sites were sampled using the Pollard line transect method (Pollard and Yates, 1993). The counts were taken between 10.00 and 15.30 local time only when the weather was sunny and the temperature was above 18°C. The transect routes were divided into sections of 500 m length, which as far as possible coincided with changes in the nature of the habitat being recorded. The length of transects in the different locations ranged between 800 m and 1000 m. The transect route was restricted to paths, the boundaries of which are easily located. Transect routes were walked at a constant pace of one km/h and all adult butterflies found within approximately 5 m on both sides and in front were recorded. The individuals that could not be identified by sight were either caught with an insect net for close examination and released or photographed. The sampling was done from January 2009 to December 2010 and 100 samples each were taken in undisturbed and disturbed sites.

Estimation of morphological characters of butterfly species: Morphological characters namely wing expanse, proboscis length and egg size were determined for the four troidine species. For obtaining wing expanse in each species, measurements of the distance between the wing tips in centimeters in fifteen well spread, preserved specimens were taken using a fine scale. The proboscis length was measured in fifteen laboratory bred and freshly emerged individuals of each species by carefully holding the butterfly sideways

Table 1. Habitat systems in the Western Ghats sampled for butterfly fauna

Habitat /Management types	Locations
National Park / Biosphere Reserve	Agasthyamalai Biosphere Reserve Eravikulam National Park Silent Valley National Park
Wildlife Sanctuary	Aralam Wildlife Sanctuary Chinmony Wildlife Sanctuary Parambikulam Wildlife Sanctuary Peechi-Vazhzani Wildlife Sanctuary Shenduruny Wildlife Sanctuary Waynadu Wildlife Sanctuary
Reserve Forest	Kalpetta Reserve Forest Periya Reserve Forest Puyankutty Reserve Forest Sholayar Reserve Forest Meppady Reserve Forest Nelliampathy Reserve Forest Vazhachal Reserve Forest
Dam/ Reservoir	Chinmony Dam Peechi Dam Vazhani Dam
Plantation	Chengalur (Monoculture plantation) Kiralur (Polyculture plantation)
Park / Garden	Kerala Forest Research Institute Butterfly Garden

and gently extending the proboscis with a fine needle and placing a thread along the length of the proboscis. The length of the thread was then measured in centimeters with a fine scale after releasing the butterfly. For determining the egg size, fifteen freshly field laid eggs of each species were brought to the laboratory. The eggs were examined under a microscope with a grid and the diameter was measured in mm.

Determination of life history traits: Life history traits namely larval development period, voltinism, phagy and susceptibility to predation and parasitism recorded. To obtain information on the larval development period, eggs collected from the field were placed in small glass tubes (2.0 cm diameter x 7.5 cm height), loosely plugged with cotton wool and containing a small piece of water-soaked tissue to maintain humidity. On hatching, larvae were transferred to sterilized glass containers (6.5 cm diameter x 13.0 cm height). The entrance of the containers were covered with a clean dry cloth and securely fastened with a rubber band. Frass and debris were removed daily and larvae removed to sterilized containers and provided with fresh leaves of the host plant. The 4th instar larvae were removed to larger containers (9.5 cm diameter x 19.0 cm height). Final instar larvae preparing for pupation were provided with a dry twig placed diagonally, leaning from the base of the container and resting against its wall. The duration of each instar was recorded. The voltinism of the four troidine species was evaluated and categorized as follows: univoltine - life cycle involves one generation per year; bivoltine - life cycle involves two generations per year and multivoltine – life cycle involves more than two generations per year. The host plant range of the four troidine species was evaluated and categorized as follows: monophagy- feeding on a single species of plants in one family, oligophagy- feeding on 10 or fewer species of plants in one family; polyphagy- feeding on 10 or more species of plants in one family and/ or on plants from two or more families. To obtain information on the susceptibility of the various stages of troidine butterflies to predation and parasitism, observations on these aspects in both field and laboratory conditions were recorded.

Larval host plant sampling and characterization

Survey method: Larval host plants of the troidines occurring in the different habitats were recorded. At each site, the area adjacent to the selected transects was thoroughly scanned to locate the host plants and record their numbers. The number of juveniles present on the located host plants were also recorded.

Determination of specific leaf area and leaf dry matter content of larval host plants: Specific leaf area and leaf dry matter content was estimated for each host plant species. For determining the specific leaf area (SLA) and leaf dry matter content (LDMC), three fully expanded leaves with attached stems were collected from robust, well-established host plants. Senescent or damaged leaves were avoided. Collected leaf-stem segments were immediately placed between wet papers, sealed in a plastic bag and placed in dark cooled containers. After being transported to the laboratory (usually within 1 hour after collection), leaf samples were placed in water in the dark at 5°C for 12 hours after the stem or petiole was removed under water (Garnier *et al*., 2001). This procedure ensured full leaf rehydration. Leaves were then dried with tissue paper to remove surface water and immediately weighed to determine their saturated fresh weight. Leaf area was then measured using grid paper. Samples were then oven-dried at 60°C for at least two days, and their dry weights were determined. Values of LDMC were calculated as the ratio between leaf dry mass and saturated fresh mass (g g^{-1}), and SLA was expressed as the ratio of leaf area to leaf dry mass (cm^2 g^{-1}). Three replicates were done for each parameter and averaged to obtain the mean value.

Characterization of host plant growth form and phenology: The growth form of the host plants was characterized into the following three categories namely (i) tree/ shrub (ii) herb/ grass and (iii) climber/ liana. For scoring the phenology of the host plants, the flowering period of the different host plants was observed and recorded.

Distribution mapping: The location of transects

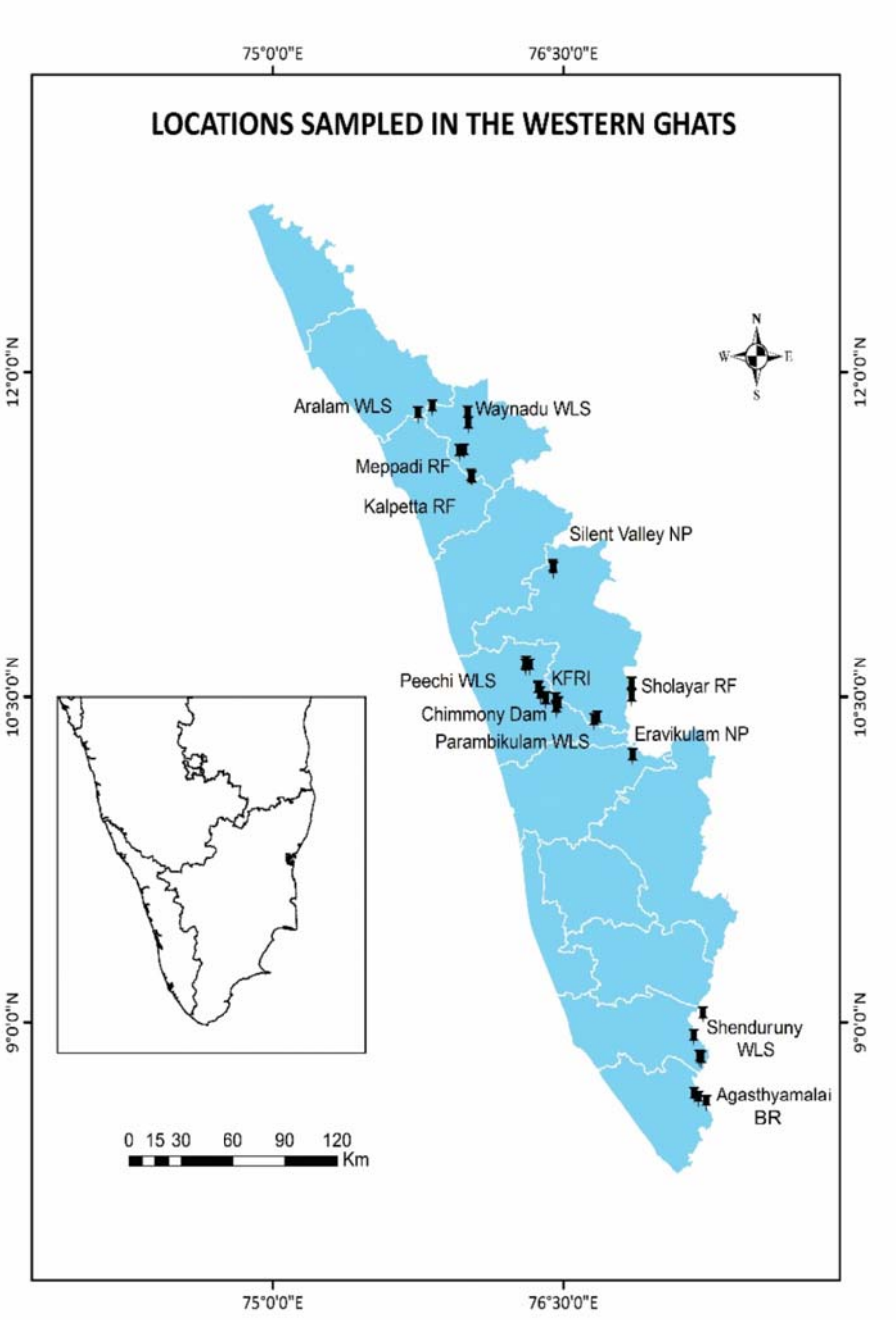

Fig. 1. Location of study sites in the Kerala part of the Western Ghats

with records of host plant occurrence was marked by using GPS (Global Positioning System) from the field. The GPS readings are plotted over geo-referenced Survey of India (SOI) by using open source GIS (Geographic Information System) software. The base layers such as water bodies, forest and boundaries were digitized from SOI topo sheets and updating of layers from latest satellite imageries using GIS and remote sensing software was done. The transects were classified according to forest/wildlife divisions of the State Forest Department and fifteen divisions were obtained of which mapping was done for the thirteen divisions where host plants were recorded. The final distribution map of troidine species in areas of host plant occurrence based on mean abundance of butterflies was prepared using GIS software (ESRI, 2011).

Habitat sampling and characterization: Environmental variables namely the weather parameters like relative humidity and mean temperature were recorded in the different habitats. The number of adult nectar plants utilized in the various habitats was scored for each species. Butterfly habitat variables like number of habitats occupied and flight period was obtained by sampling. Information on biogeographical range was obtained from literature and scored for each species. The geographical distribution ranges were categorized on a scale of 1-6 (smallest to largest) as follows: 1- Western Ghats, 2- South and Peninsular India, 3- Indian subcontinent, 4- Oriental (Indo-Malayan), 5- Paleotropics, 6- Cosmopolitan.

Soil sampling and characterization: In order to obtain information on the soil characteristics in the different habitats where the host plants of the troidines were recorded, soil was sampled at 48 locations. Within the selected sites, soil samples were collected at 3 random locations at 0-20 cm depth. These samples were pooled and the following edaphic variables were estimated: pH, total soluble solutes (TSS), organic carbon (OC), phosphorus (P) and potassium (K). Eight replicates were obtained in each habitat and averaged to obtain the mean.

Data analysis: The correlation between the habitats based of the abundances of the four troidine species in the different habitats was sought. The correlation analysis of the troidine butterfly abundance and the habitat variables namely soil properties, temperature and humidity was also done.

RESULTS AND DISCUSSION

Butterfly sampling and characterization: When considering the abundance of the troidines in the various habitats (Fig. 2) it was observed that *P. aristolochiae* was the most widely distributed species occurring in 90% of the transects sampled and having the highest abundance in the reserve forests and wildlife sanctuaries. *P. pandiyana* had a restricted distribution occurring in only 36% of the sampled transects with main populations in the national parks, wildlife sanctuaries and garden habitats. Both *P. hector* and *T. minos* were observed in 73% of the transects. *P. hector* showed maximum numbers in the reserve forests while *T. minos* numbers peaked in wildlife sanctuary habitats. There are varied morphological characters and life history traits (Table 2). *T. minos* had two generations in a year, *P. pandiyana* had one generation while both *P. hector* and *P. aristolochiae* had several generations. When

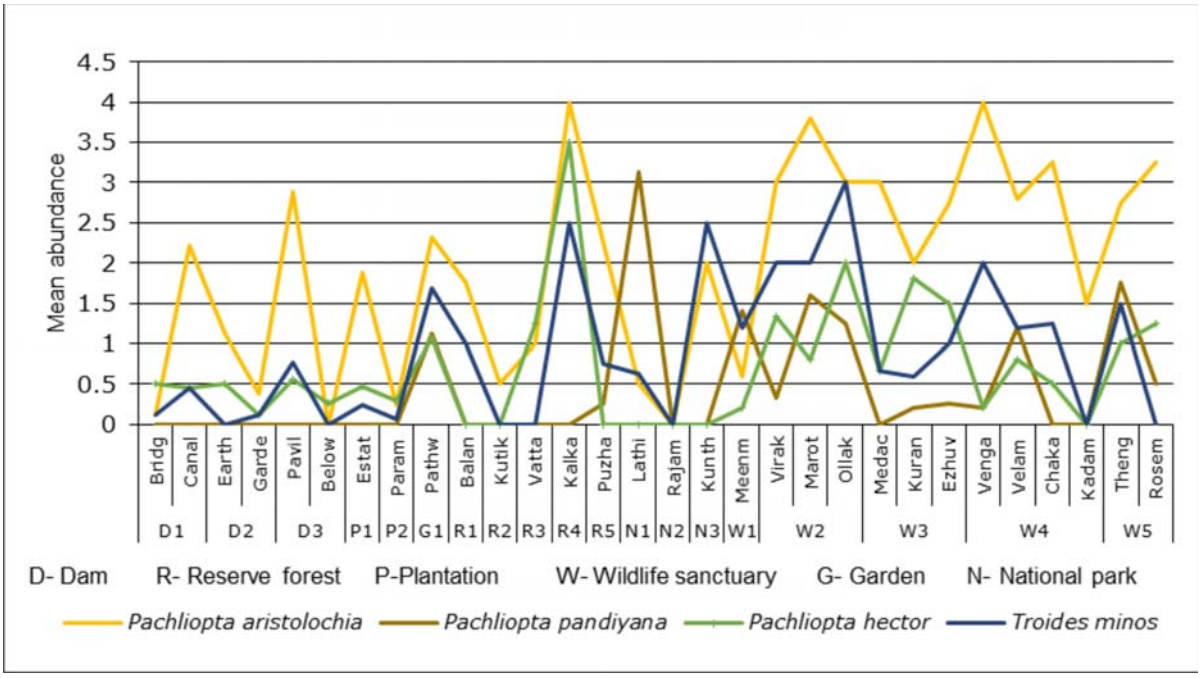

Fig. 2. Mean abundance of troidines in the different habitats sampled during 2009 and 2010

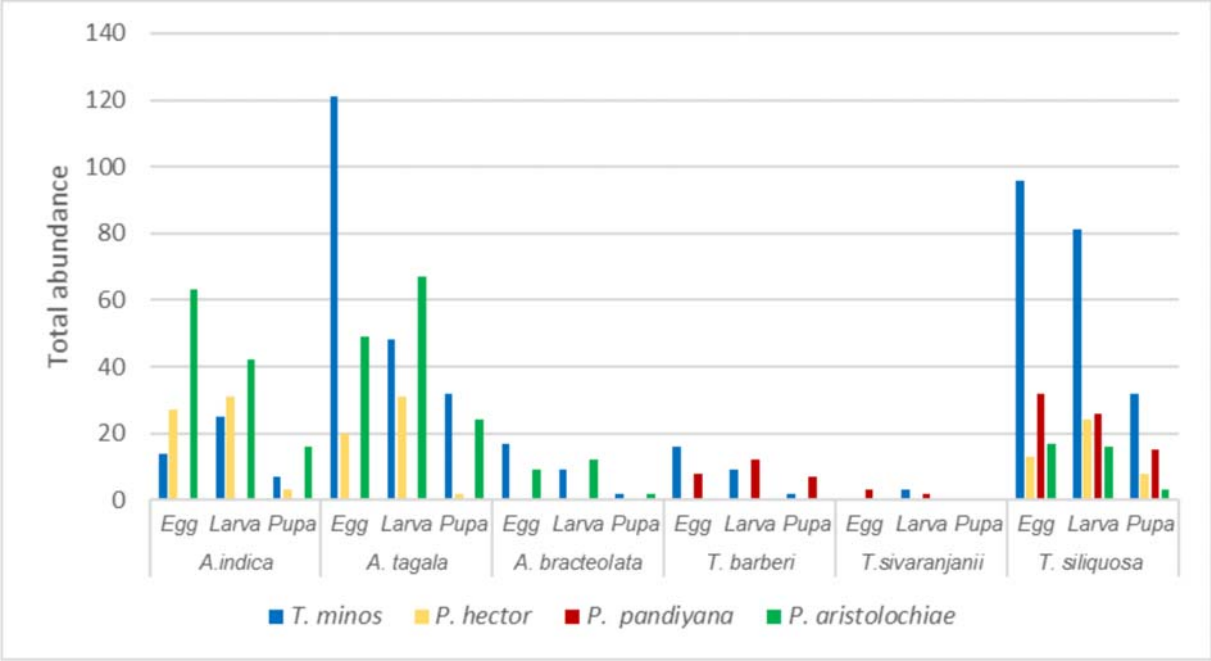

Fig. 3. Total abundance of juveniles of troidines recorded on different host plants in all habitats during 2009 and 2010

considering feeding preferences, *P. pandiyana* was observed to only feed on *Thottea* species while the other three troidine species were oligophagous feeding on both *Aristolochia* as well as *Thottea* species. A hymenopteran egg parasitoid, *Telenomus dilates* sp.n. was reported for the first time in the eggs of *T. minos* and *P. aristolochiae* (Rajamohana and Anto, 2014). A dipteran larval parasite and a hymenopteran pupal predator were also recorded in *T. minos*.

Larval host plant sampling and characterization: Six species of the family Aristolochiaceae were recorded as the larval host plants of the four species of troidine butterflies in the different habitats that were sampled in the study. The data obtained from the sampling of juveniles on the six species of host plants in the various habitats (Fig. 3) provide some insights into host plant partitioning between the conspecific species of butterflies in the different habitats. *T. minos* was the only troidine which utilized all six of the recorded host plant species. *A. tagala* recorded the highest count of juveniles of *T. minos* while *T. sivarajanii* had the lowest count. *P. aristolochiae* utilized four species of host plants with *A. tagala* recording the highest count of juveniles followed by *A. indica*. *P. hector* also utilized four species of host plants and the highest count of juveniles was obtained on *A. indica* followed by *T. siliquosa*. *P. pandiyana* utilized three species of host plants all belonging to the *Thottea* species with *T. siliquosa* recording the highest count of juveniles followed by *T. sivarajanii*. Observations indicate that *A. tagala* was the host plant species which recorded highest count of troidine juveniles followed by *T. siliquosa*. Hence the observed pattern of host plant utilization of *T. minos* which uses all of the six recorded *Aristolochia* species hints of an ancestral host plant use characteristic of basal taxa for this species (Silva Brandão *et al*., 2005). On the other hand, *P. pandiyana* has a restricted host range using fewer species thereby showing features of a more specialized terminal taxa (Kelly and Farrel, 1998). The highest specific leaf area (SLA) as well as leaf dry matter content (LDMC) was recorded in *A. tagala* followed by the endemic *T. sivarajanii* (Table 3). When considering the distribution of the host plant species across habitats, it was observed that the wildlife sanctuaries and gardens supported more larval host plant species followed by national parks and reserve forests. The plantations and

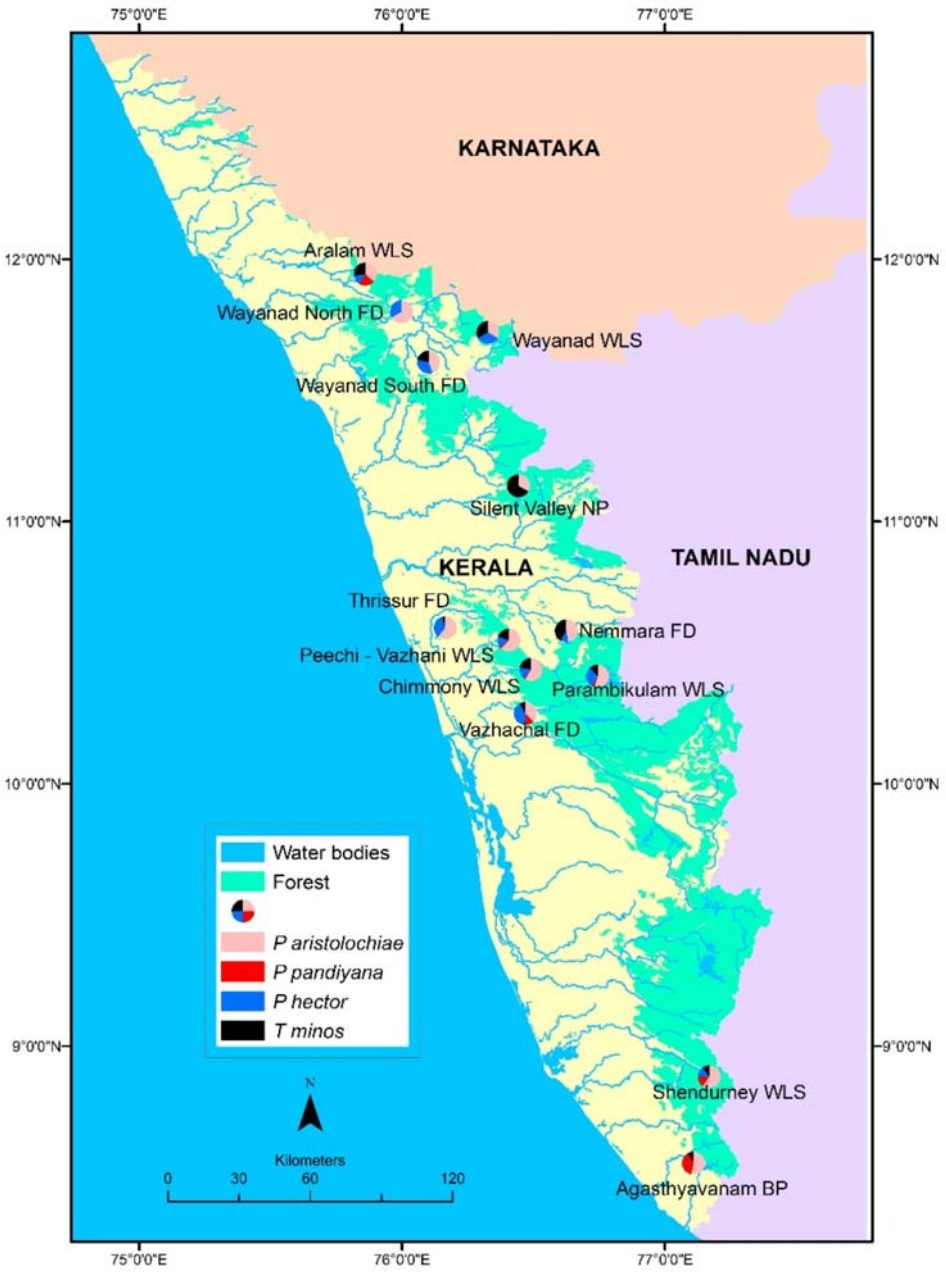

Fig. 4. Distribution map of troidines based on mean abundance of adults in transects with host plant occurrence in the habitats sampled during 2009 and 2010

dams were comparatively poorer in host plant species.

Distribution mapping of Troidines: The distribution of the troidine species based on occurrence of larval resource plants in the sampled sites was mapped (Fig. 4). The mapping of the resource plants for this group of butterflies across the various habitats was attempted keeping a species-centered view of the landscape (Fischer *et al*., 2004). In tropical regions, the distribution of a species across landscapes and its persistence depends on many factors of which mobility through modified "countryside" habitats (Gascon *et al*., 1999) is critical. Among the troidines, *P. aristolochiae* and *T. minos* having the broadest host plant ranges occurred in 86% and 80% of the divisions respectively. *P. hector* was sighted in 73%

Table 2. Morphological characters and life history traits of the troidine species

Traits/Characters	min	pan	hec	ari
Larval period (mean± SE in days)	28.2±0.698	30.3±0.987	27.8±0.578	25.4±0.532
Wing span (mean± SE in cm)	13.84±0.252	10.64±0.183	9.94±0.119	8.85±0.077
Proboscis length (mean± SE in cm)	2.99±0.051	2.15±0.037	1.48±0.036	1.28±0.020
Egg size (mean± SE in mm)	1.842±0.052	1.506±0.021	1.358±0.011	1.230±0.012
Voltinism	bivoltine	univoltine	multivoltine	multivoltine
Phagy	oligophagy	monophagy	oligophagy	oligophagy
Predators	pupal	none recorded	none recorded	none recorded
Parasites	egg, larval	egg	none recorded	egg

SE = Standard error.
Butterfly species codes = min - *Troides minos*, pan - *Pachliopta pandiyana*, hec - *Pachliopta hector*, ari - *Pachliopta aristolochiae*.

Table 3. Specific leaf area (SLA), leaf dry matter content (LCDM), growth form, phenology, butterfly hosts and occurrence of larval host plants.

Host plant species	SLA (cm^2g^1)	LDMC ($g\,g^{-1}$)	Growth form	Phenology	Butterfly host species	Habitat systems
Aristolochia indica	0.087	0.44	climber/ liana	June-Oct	min, hec, ari	P, D, G
Aristolochia tagala	0.271	1.36	climber/ liana	Oct-Feb	min, hec, ari	WS, G
Aristolochia bracteolata	0.130	0.65	climber/ liana	Jun-Sep	min, hec, ari	WS, G
Thottea siliquosa	0.243	1.22	tree/ shrub	May-Dec	min, pan, hec, ari	WS, G, RF
Thottea barberi		0.097	0.49	tree/ shrub	Jun-Sep	min, pan NP, WS, G
Thottea sivarajanii	0.263	1.32	tree/ shrub	Oct-Jan	min, pan	NP, WS, RF

Habitat codes = NP-National park/ Biosphere reserve, WS-Wildlife sanctuary, RF-Reserve forest, D-Dam, P-Plantation, G-Garden.
Butterfly species codes = min-*Troides minos*, pan- *Pachliopta pandiyana*, hec - *Pachliopta hector*, ari - *Pachliopta aristolochiae*

Table 4. List of habitats occupied, flight period and biogeographical distribution range of troidine species

Troidine Species	Habitatsoccupied	Flight period (months/year)	Biogeographical range
Troides minos	NP,WS,RF,D,P,G	10	2
Pachliopta pandiyana	NP,WS,R,G	5	1
Pachliopta hector	WS,RF,D,P,G	8	3
Pachliopta aristolochiae	WS,RF,D,P,G	12	4

Habitat codes = NP-National park/ Biosphere reserve, WS-Wildlife sanctuary, RF-Reserve forest, D-Dam, P-Plantation, G-Garden.
Geographical distribution range codes = 1-Western Ghats, 2- South and Peninsular India, 3-Indian subcontinent, 4-Oriental, 5- Paleotropics, 6- Cosmopolitan

Table 5. Soil properties, troidine mean abundance and environmental conditions at selected sites in the various habitats

Habitat systems	Soil properties					Troidine abundance (Mean±SE)				Environmental conditions (Mean±SE)	
	pH	TSS	OC	P (kg/ha)	K (kg/ha)	min	pan	hec	ari	Temp (°C)	RH (%)
National park	5.21	0.13	1.06	7.17	155.37	0.87± 0.56	1.5± 0.92	0	0.12± 0.17	20.28± 0.95	81.13± 2.62
WL sanctuary	5.9	0.12	1.10	24.07	246.75	1.12± 0.56	0.7± 0.44	0.25± 0.23	0.87± 0.62	31.23± 1.54	61.88± 4.81
Reserve forest	5.47	0.20	1.11	16.2	189.75	0.75± 0.74	0.12± 0.17	0.87± 0.62	0.87± 0.49	31.19± 0.71	69.75± 2.61
Dam	5.91	0.1	0.91	27.35	224.25	0.37± 0.37	0	0.5± 0.37	1.12± 0.56	38.25± 1.46	60.74± 4.09
Plantation	5.52	0.1	0.88	5.37	170.87	0	0	0.37± 0.37	1.12± 0.49	38.96± 1.85	58.50± 3.24
Garden	6.15	0.1	0.72	12.82	198.62	1.5± 0.59	1.2± 0.79	0.75± 0.79	2.12± 0.72	37.11± 1.88	64.25± 4.29

Table 6. Correlation matrix of troidine abundance in different habitats

	NP	WS	RF	D	P	G
NP	1					
WS	0.44501	1				
RF	-0.91222	-0.11826	1			
D	-0.79576	0.06052	**0.77540**	1		
P	-0.71583	-0.08006	0.57442	**0.94491**	1	
G	-0.05208	**0.71796**	0.17128	**0.64281**	**0.61844**	1

Table 7. Pearson correlation coefficients (r^2) between troidine abundance and soil properties, temperature and humidity

Troidine Species	pH	TSS	OC	P (kg/ha)	K (kg/ha)	Temp (°C)	RH (%)
Troides minos	**0.5432**	-0.0495	-0.3371	0.0497	0.1991	-0.1114	0.2763
Pachliopta pandiyana	-0.1858	-0.0351	0.1017	-0.3098	-0.2595	**-0.7708**	**0.9219**
Pachliopta hector	0.3684	0.3111	-0.3189	0.1247	0.1153	0.1153	**-0.7974**
Pachliopta aristolochiae	**0.7667**	-0.3903	**-0.8517**	-0.0195	0.1517	**0.5963**	-0.4250

Bold numbers indicate significant correlation (pe" 0.05). Soil properties= pH-ion concentration, TSS-Total soluble solutes, OC-Organic carbon, P-Phosphorus, K- Potassium, Temp (°C)-Temperature in degrees centigrade, RH (%)- Relative humidity expressed as a percentage, (kg/ha)-kilogram per hectare

Table 8. List of nectar plants of Troidine butterflies recorded in the various habitat systems

Troidine species	Nectar plant species	Habitat systems
min, pan, hec, ari	*Clerodendrum paniculatum*	RF, P, D, G
min, hec, ari	*Clerodendrum viscosum*	RF, P, D, G
min, pan, hec, ari	*Ixora coccinea*	D, G
min, pan, ari	*Ixora nigrans*	WS, RF, D, G
min, pan	*Ixora malabarica*	NP, WS
min, hec, ari	*Mussaenda glabra*	D, G
min, pan	*Mussaenda parviflora*	NP, WS
min, pan, hec, ari	*Mussaenda frondosa*	D, G
min, pan, hec, ari	*Mussaenda ethryophyllum*	D, G
hec, ari	*Nerium odorum*	D, G
hec, ari	*Carissa carandus*	D, G
hec	*Albizzia lebbeck*	P, D
min, pan, hec, ari	*Lantana camara*	RF, P, D, G
min, hec, ari	*Pentas sp.*	D, G

Habitat codes = NP-National park/ Biosphere reserve, WS-Wildlife sanctuary, RF-Reserve forest, D-Dam, P-Plantation, G-Garden. Butterfly species codes = min-*Troides minos*, pan- *Pachliopta pandiyana*, hec - *Pachliopta hector*, ari - *Pachliopta aristolochiae*

and the monophagous *P. pandiyana* in only 46% of the divisions. All the wildlife sanctuaries with the exception of the Wayanad Wildlife Sanctuary sustained populations of all the four troidine species. Similarly among the forest divisions, Vazhachal Forest Division had populations of the four species. The Agasthyavanam Biological Park had the largest population of the endemic species, *P. pandiyana*.

Habitat sampling and characterization: Butterfly habitat variables include number of habitats occupied, flight period and biogeographical range (Table 4). The lowest ranked species, *P. pandiyana* with score 1 was endemic to the Western Ghats and the highest ranked species, *P. aristolochiae* with a score 4 was the most widely distributed species with an Oriental distribution. *T. minos* has a peninsular distribution and *Pacliopta hector* is found in the Indian subcontinent. No species with geographic range scores of 5 and 6 were recorded among the troidine species in our study. *T. minos* occurs in all the habitat types, *P. aristolochiae* and *P. hector* were not recorded in biological reserves and *P. pandiyana* was absent in dams and plantations. The values obtained for the various soil parameters, mean troidine abundance and the temperature and humidity conditions are given in Table 5.

Correlation: The correlation between habitats based on the butterfly abundance of the four troidine species evaluated (Table 6) indicated that while all three different disturbed habitats were significantly correlated to one another, none of these had a significant correlation to undisturbed habitats. This further emphasizes the well documented fact that relatively undisturbed habitats namely national parks, wildlife sanctuaries and reserve forests are the key areas to be targeted for conservation management. Among the man-modified habitats, the gardens were significantly correlated to wildlife sanctuaries and the dam sites to the reserve forests. This finding is significant as it further supports previous studies (Mathew and Anto, 2007, Mathew *et al*., 2011) which demonstrate that artificially created parks and gardens with diverse larval and adult resources and managed with respect to the ecological needs of butterfly species can attract and sustain viable populations in the area.

The correlation analysis of the troidine butterfly abundance and the habitat variables namely soil

properties, temperature and humidity (Table 7) show that some of these factors are strongly correlated to the occurrence of species in the various habitats. The occurrence of *P. pandiyana* was limited by humidity and temperature levels of the habitats. It was observed only at humidity levels of 85% and above and low temperatures (negative correlation). *P. hector* on the other hand was found in areas of low humidity levels and higher temperatures. *P. aristolochiae* showed positive correlation to temperature. Among the soil edaphic factors only pH and organic carbon appeared to be significant.

Since the host plants in a habitat are utilized only when sufficient adult resources (nectar) are also available, optimal butterfly habitat must include sufficient larval and adult food resources. In the present study, the maximum number of troidine species and individuals were observed in wildlife sanctuaries and garden habitats (Table 8) where availability of diverse plants and access to host plants promoted the butterfly richness and density. Most of these plants provide rich nectar sources to adult butterflies. Comparatively, the other habitats especially plantations and dam sites have lesser density of vegetation. The vegetation in national parks is highly specialized and that of the reserve forests are less species rich in character. The dams and plantations being subject to anthropogenic activities have lower butterfly colonization.

Among the biodiversity hotspots, Western Ghats has the highest human population living in close proximity to the forests resulting in human disturbance being the single most important factor in the deterioration of habitat quality and loss of biodiversity. In the case of forest landscapes in the Western Ghats, the disturbance regime in terms of timber and other forest produce extraction has evolved along with the livelihood practices of native as well as settler populations over the past centuries. Protected areas like national parks, biological reserves and reserve forests are undoubtedly strategic conservation areas for rare species and their protected status help maintaining human impacts at minimal levels. However, the proportion of these areas is clearly not sufficient to support the rich and diverse fauna of the region. Hence, managed habitats like bio parks and butterfly gardens incorporating a wide range of artificially created conditions have the potential to provide refuge to a diverse assemblage of butterfly species. Therefore, sustainably and ecologically managed areas providing economic benefits may complement the "large protected area" concept which is becoming increasingly impractical in our resource crunched world. Ultimately, the future of many species will be determined by how well they adapt life history strategies in a mosaic of urban, agricultural, semi natural and natural habitats. Thus, equipped with a better understanding of ecological processes of selected species in natural and human modified landscapes, the sustainability of traditional land use patterns can be reassessed with greater clarity.

The troidine species of butterflies are a group of distinctly patterned butterflies which are easily detectable in field surveys and has been proposed as an ideal group for monitoring by forest guards on a routine basis along forest tracks (Anto and Mathew, 2014). The selection of taxa for conservation has always been a dilemma as sampling of entire faunas is practically impossible. Endemicity of plants and animals is considered a very important criteria for conservation purposes. Moreover, taxa that are endemic to a single geographic area are singularly relevant as their conservation will be policy-based and local. This study is significant as it focuses on the four troidine species of the Western Ghats area namely:- *Pachliopta pandiyana* (Western Ghats endemic); *Troides minos* (Peninsular India endemic and CITES listed species); *Pachliopta hector* (listed in Schedule I of Indian Wildlife Protection Act) and *Pachliopta aristolochia*. The larval host host plants of these butterflies also include endemic and RET species namely *Aristolochia indica, Aristolochia tagala, Aristolochia bracteolata* and *Thottea siliquosa*. Thus information generated on their utilization within the Kerala part of the Western Ghats is particularly relevant as *Aristolochia indica* is widely used in traditional medicine and regularly extracted from the forest areas. Further studies on troidines and other threatened invertebrate/plant taxa will probably provide more robust correlations and definitely demands further investigations.

As human impacts on ecological systems escalate, it is important to understand the complex dynamics and interactions in natural ecosystems. The distribution mapping has helped understand the patterns of larval resource use in the selected habitats. Further, interactions such as predation, competition and parasitism and their influence on the structure of butterfly communities needs further research and analysis. In the Kerala part of the Western Ghats where a sizeable proportion of the population live near forests and many activities are forest-dependent, an ideal sustainable conservation model would be one which balances the future of biodiversity with the livelihood of the people. Once this crucial equation is computed, it will definitely show the way forward in this ecologically fragile and politically sensitive region.

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Monitoring global public health threat - surveillance of *Aedes* (*Stegomyia*) mosquitoes in new Mangalore sea port, India

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ABSTRACT: Vector surveillance and control at port of entry (PoE) is an essential activity for the implementation of International Health Regulations (IHR). The present study was undertaken in and around New Mangalore sea port. Inside the port area, a total of 13 water holding containers at 33 premises were checked and no containers were found positive for larval breeding. In the residential area, 132 water holding containers were checked in 100 houses. The breeding preference ratio was highest for earthen containers (18.8) followed by grinding stone (4.72), metal (1.72), cement tank (1.62) and plastic (0.24). The House index, Container index and Breteau index were found to be 7.0, 5.3 and 7.0% respectively. The nearness of residential colony to NMPT, consequently enhances the chances of spreading of *Aedes* mosquitoes in the port area. From the present study it is evident that inside the sea port there are ample habitats for the mosquitoes to breed and thrive in rainy season. Routine entomological surveillance is required not only to monitor the mosquito breeding in and around port area but also to prevent transportation and establishment of mosquito species in newer areas.

KEY WORDS: International health regulation, public health threat, breeding preference ratio

INTRODUCTION

Vector borne diseases pose a major public health concern today, with a number of 'old' diseases resurging in recent decades along with newly emerging infectious diseases. Mosquitoes transmit some of the world's worst life threatening and debilitating parasitic and viral diseases. Some of these were effectively controlled since few decades, but such hardwon gains are now threatened. Among the invasive mosquitoes registered all over the world, *Aedes* species are particularly frequent and grave. As several of them are potential vectors of disease, they present significant health concerns. The routes of importation and spread are often enigmatic, the ability to adapt to local environments and climates are rapid, and the biting nuisance and vector potential are both an economic and public health distress (Gubler, 2002; Smolinski *et al.,* 2003; Medlock *et al*., 2015).

Aedes mosquitoes originally found in tropical and subtropical zones carry a variety of pathogens that can be transmitted to humans. The species *Aedes aegypti* and *Ae. albopictus* are the primary vectors of alarm world wide. *Ae. aegypti* mosquito is the main vector that transmits the viruses that cause dengue, chikungunya, yellow fever and zika virus. *Ae. albopictus* is a principal urban vector for the

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transmission of dengue virus and a competent vector of 22 arboviruses, including West Nile and Yellow fever viruses (Gubler, 2003). *Aedes* mosquito is considered a highly domesticated mosquito, very adapted to living with man, preferring to rest indoors and to feed on humans during daytime hours. The *Aedes* mosquitoes generally breed in water holding containers found in and around the houses, such as those used for water storage, flower vases, mud containers, metal containers, used tires, plastic utensils and other receptacles that collect rain water (Sheela Devi *et al.*, 2012).

The incidence of vector borne diseases is increasing alarmingly due to many factors including uncontrolled urban developments that support breeding of vector mosquitoes. In India, National Vector Borne Disease Control Program (NVBDCP) reported 28,292 dengue cases and 110 deaths in 2010 from 35 states in India. In the same year, in Karnataka 2285 dengue fever (DF) cases and 7 deaths were reported. After six years, in 2017, in India the reported DF Cases rose to 1, 57,220 and 250 deaths. Karnataka, on the other hand, reported 17018 dengue fever cases and 5 deaths in 2017. There is an increase of 7.5 times DF cases in Karnataka over a span of six years. Similarly, 48176 clinically suspected chikungunya fever cases were reported in 2010 from 30 states in India and in 2017 the chikungunya fever cases in the country rose to 62268. In 2010 the clinically suspected chikungunya cases reported in Karnataka state were 8740 and 3.2 times increase ie, 31644 chikungunya cases were reported from the state in 2017.

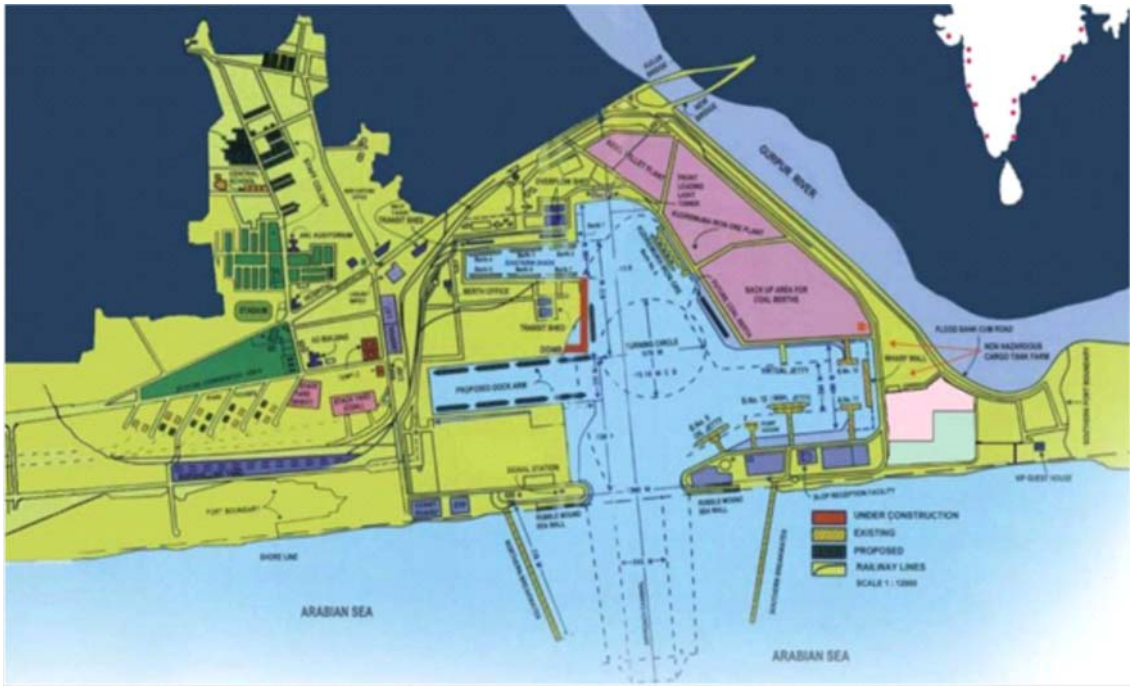
The transport of mosquitoes beyond their native range via shipping, aircraft and transport has been well documented, particularly in the expansion of *Ae. albopictus* via shipping of used tyres (Schotle and Schaffner, 2007) and the occurrence of vectors of yellow fever, dengue and malaria on aircraft (De Hart, 2003). Moreover, India shares sea route/ connection with majority of yellow fever (YF) endemic countries. This raises more concern in India to control *Aedes* mosquito breeding in seaport areas to prevent any introduction of YF virus in the country. Presence and prevalence of mosquitoes in and around ports makes this issue more rucil. Moreover, under the WHO International Health Regulation (WHO, 2016), all International airports and seaports should be kept free from all types of mosquito vectors for a distance of 400 meters around the perimeter of the ports to achieve the ultimate aim of public health security. Thus, vector surveillance and control at port of entry (PoE) has become an essential and pressing need for the implementation of International Health Regulations (IHR). Accordingly, an eco-entomological survey was undertaken to know the present scenario of entomological indices - key *Aedes* breeding habitats, behavior of vector mosquitoes, and so forth - in and around Mangalore sea port area to assess global public health threats.

MATERIALS AND METHODS

Study area:

New Mangalore Port Trust (NMPT) Area is located on the alluvial plain, and is about 10 km north of Gurupur and the Netravathi rivers. New Mangalore Port is a lagoon type harbor with a long approach channel artificially created by dredging. The coordinates of Port are Latitude 12^0 55^1 North and Longitude 74^0 48^1 East. It is deep water, all-weather port at Panambur, Mangalore in Karnataka state in India which is also the deepest inner harbor on the west coast. It is located on the west coast of India and one of 12 major ports of India; it is the only major port in the state of Karnataka (Map 1).

The port comprises three doc systems via, Eastern Doc arm, Oil Doc arm and the Western Doc arm; it has in all 15 berths. The port serves hinterland of Karnataka state and to some extent the state of Kerala. The major commodities exported through the port are iron ore concentrates and pellets, iron ore fines, manganese, granite stones, coffee, cashew and containerized cargo. The major imports of the port are crude and petroleum products, LPG, wood pulp, timber logs, finished fertilizers, liquid ammonia, phosphoric acid, other liquid chemicals and containerized cargo. The climate is governed by the monsoons. During the months June-September, the south-west (SW) monsoon occurs.



Map 1. Operational areas of New Mangalore Port

The later period is often indicated as the post-monsoon period. The average annual rainfall is 3,467 mm. The rainfall is concentrated in the SW monsoon (June to September). During this period the average rainfall is as much as 84% of the total rainfall. The temperature varies from 22^0C to 36^0C. The low temperatures occur during south west monsoon in December and January. The hottest months are from March to May. The humidity is high throughout the year.

Residential area:

To assess the *Aedes* mosquito prevalence around the port area 100 houses were randomly selected in the NMPT Staff Colony Quarters. There are 391 houses in Type I to VII which include New and Old houses. In Type A-D there are 172 houses, 100 houses are in Registered Cargo handling Workers colony, 45 houses for CISF and altogether there are 708 houses in NMPT Staff Colony. The present Entomological surveillance was done covering all the types of houses. The ecological conditions of all the house premises were closely monitored to assess the mosquitogenic and local hygiene conditions.

Entomological surveillance:

Aedes survey was done in all the operational areas of New Mangalore port and in randomly selected 100 residential houses around the port on the last week of January 2018. Present entomological surveillance for immature and adult mosquitoes was undertaken in and around NMPT. Standard entomological techniques were used for survey. Qualitative larval sampling was conducted in all permanent/ temporary aquatic habitats. Larval survey was carried out in all types of water holding containers to detect the breeding of *Aedes (Stegomyia)* mosquitoes in and around the port. All accessible larval breeding habitats like discarded tyres, mud, plastic and metal containers, cement tanks etc were inspected. The collected larvae were identified microscopically / after adult emergence as per guidelines (WHO, 1995).

The type of breeding habitats and their location were recorded on a pre designed proforma for classification. The data on larval survey were analyzed and calculated in terms of House Index (HI), Container Index (CI), Breteau index (BI) and the preferred breeding habitats of *Aedes* mosquitoes

also assessed.The dry containers seen scattered in the premises were also examined as these can act as breeding sources of *Aedes* mosquitoes during rainy days.

RESULTS AND DISCUSSION

Port area: Entomological surveillance was done at New Mangalore Port Trust (NMPT) area during 22nd to 25th January 2018. A total of 13 water holding containers at 33 premises examined revealed no containers were found positive for *Aedes* larvae (Table 1). Of the total 13 water holding containers checked, 61.54% were plastic followed by metal (30.76%) and discarded tyres (7.7%). Attempts made for the dry containers seen scattered in the premises of NMPT operational area indicated that of the total 40 dry containers noted, 80% were discarded tires followed by metal (12.5%) and plastic (7.5%) containers.

Residential area: *Aedes* surveillance undertaken in the hundred houses showed that out of the total 132 containers with water examined, 59.09% were plastic followed by cement tank (26.53%), metal (8.33%), grinding stone (3.03%), fridge (2.27%) and earthen utensils (0.76%). A total of seven water holding containers were positive for *Aedes* larvae. Of these 42.86% were cement tanks followed by earthen (14.29%), metal (14.29%), plastic (14.29%) and grinding stone (14.29%).

The house index (HI), container index (CI) and Breteau index (BI) was found to be 7.0, 5.3 and 7.0% respectively (Table 2). The larvae and adult mosquitoes collected were identified as *Aedes albopictus.* Container preference reflected by the Breeding Preference Ratio (BPR) was maximum for earthen (18.80) followed by grinding stone (4.72), metal (1.72), cement tank (1.62) and plastic (0.24) (Table 3).

An attempt made to collect adult mosquitoes in the residential colony, showed *Aedes albopictus* mosquitoes and the per man-hour density was recorded as 2.3.

International travel and transport play an important role in the spread of vector borne diseases (VBDs) all over the world. VBDs are reported in over 100 countries, and put up to 60% of the world's population at risk of infection; more than 500 million cases are reported every year (WHO, 2016). The vast development of shipping industry and expansion of port cities during the past two centuries has led to the global spread of vector mosquitoes and pathogens related to vector borne diseases.

A total of 33 premises were searched inside the sea port. Of the total 13 water holding containers seen, none of them found positive for *Aedes* larvae. Entomological surveillance undertaken in the January- February is the beginning of dry season where the temperature varies from 22^{0}C to 36^{0}C and the relative humidity ranges from 50% to70%. During the dry and hot condition maximum number of containers inside the port was without water. The nil *Aedes* positivity inside the port substantiates the dry and hot condition of the post monsoon period.

In the study on the breeding prevalence of vectors of dengue/ chikungunya and yellow fever, Sharma and Kumar (2015) could not find the breeding of *Aedes* mosquitoes inside Chennai sea port. While studying the breeding habitats of vector mosquitoes in Marmugao Port Trust (MPT), Goa, Patel *et al.* (2017) also reported a similar situation.

Of the total 40 dry containers/ sources seen inside the sea port, 32 (80%) were tyres. During monsoon the dry containers especially tires may get filled with rain water and pave for the breeding of *Aedes* mosquitoes. In order to avoid mosquito breeding either these containers are to be removed or kept properly covered. *Aedes* mosquito breeding could be noted in the present surveillance in the residential areas. Several dry containers seen scattered in the house premises intensify the breeding of *Aedes* mosquitoes in this area during monsoon season. The closeness of the residential colony to sea port enhances the chances of spreading spill over of breeding of *Aedes* mosquitoes in the port area.

The present study indicated that in residential areas around NMPT area, the Breeding Preference Ratio (BPR) was highest for earthen containers (18.8) followed by grinding stone (4.72), metal (1.72), cement tank (1.62) and plastic (0.24). A study on

Table 1: Surveillance of *Aedes m*osquitoes at operational areas of New Mangalore Port

Sl. No.	Premises	Water holding containers						Dry containers available		
		Plastic		Metal		Tyre		Plastic	Metal	Tyre
		S	P	S	P	S	P			
1	Container Yard	_	_	_	_	1	_	_	_	20
	Silver jubilee Gate(wharf)									
2	Hasan &Hajee Company	_	_	_	_	_	_	_	_	_
3	Deployment office	_	_	_	_	_	_	_	_	_
4	Amogha logistics, Amogha shipping agency	_	_	_	_	_	_	_	_	_
5	Cochin Shipping company	_	_	1	_	_	_	_	_	_
6	Indian Shipping Agency	_	_	_	_	_	_	_	_	1
7	Asprin wall & Co	_	_	_	_	_	_	_	_	_
8	Sri Ganesh shipping agency	_	_	_	_	_	_	_	1	_
9	Worldwide shipping	_	_	_	_	_	_	_	_	_
10	Export trade link agency	_	_	_	_	_	_	_	_	_
11	Konkan Marine agency	_	_	_	_	_	_	_	1	_
12	Iron or coal Berth	_	_	2	_	_	_	1	2	3
13	Yojaka Workshop	3		1	_	_	_	_	1	1
14	Berth No. I	_	_	_	_	_	_	_	_	_
15	Berth No.II	_	_	_	_	_	_	_	_	_
16	Berth No. III (Costa Classica Ship)	_	_	_	_	_	_	_	_	3
17	Berth No. IV(Passenger Lounge &Cruise Lounge)	_	_	_	_	_	_	_	_	2
18	Berth No. V	_	_	_	_	_	_	_	_	1
19	Berth No. VI	1	_	_	_	_	_	_	_	_
20	Berth No. VII-XIII	_	_	_	_	_	_	_	_	_
21	Berth No. VIII	_	_	_	_	_	_	_	_	_
22	Berth No. IX	_	_	_	_	_	_	_	_	_
23	Berth No. X	_	_	_	_	_	_	_	_	_
24	Berth No. XI	_	_	_	_	_	_	_	_	_
25	Berth No. XII	_	_	_	_	_	_	_	_	_
26	Berth No. XIII	_	_	_	_	_	_	_	_	_
27	Berth No. XIV-west	1	_	_	_	_	_	_	_	_
28	Berth No. XIV East	_	_	_	_	_	_	_	_	1
29	Berth No. XV Adani	_	_	_	_	_	_	_	_	_
30	NMPT	_	_	_	_	_	_	1	_	_
31	Port fire station area	2	_	_	_	_	_	_	_	_
32	Control room area	_	_	_	_	_	_	1	_	_
33	Oil terminal and Traffic Department area	1	_	_	_	_	_	_	_	_
	Total	8	-	4	-	1	-	3	5	32

S – Searched for *Aedes* larvae; P – Positive for *Aedes* larvae

Table 2: *Aedes* larval indices in the residential areas of New Mangalore Seaport

No of houses searched	Houses positive for *Aedes* Larvae	Total containers searched	Containers positive for *Aedes* Larvae	House/ Premise Index (HI-%)	Container Index (CI-%)	Breteau Index (BI)
100	07	132	07	07	5.3	07

Table 3: Breeding habitats of *Aedes* Mosquitoes in the Residential areas of New Mangalore Seaport

Sl No	Type of water holding containers	Searched	Positive for *Aedes* Larvae	Breeding Preference Ratio(BPR)
1	Mud pots/ Flower pots	01 (0.76)	01(14.29)	18.80
2	Metal	11 (8.33)	01 (14.29)	1.72
3	Plastic	78 (59.09)	01 (14.29)	0.24
4	Cement Tank	35 (26.53)	03 (42.86)	1.62
5	Grinding Stone	04 (3.03)	01 (14.29)	4.72
6	Fridge	03 (2.27)	0 (0)	0
	Total	132	07 (5.30)	

Figures in parentheses indicate percentage value

the entomological surveillance for the vectors of yellow fever/ dengue/ chikungunya in and around Port of Goa, Sharma *et al*. (2015) reported the earthen containers are the most preferred breeding source of *Aedes* mosquitoes in the residential area of Goa sea port. It is also noted that during dry season the inhabitants force to store water in cement tanks which enhances the chances of *Aedes* breeding. This situation necessitates further strengthening of ecology/entomology based control methods besides community awareness on local factors responsible for *Aedes* breeding.

The main intention of entomological surveillance in international airports/seaports is to maintain vector free status through appropriate vector control measures. Mosquito breeding surrounding seaport and / or International board is not just a simple local health problem; it is a serious threat to global health security. A careful invigilation of the international airports and seaports by the trained scientists/vector control personnel is recommended to prevent breeding and export of vector species. Routine entomological surveillance is required not only to monitor the mosquito breeding in and around port area but also to prevent the transportation and establishment of mosquito species in new countries, regions and continents as a result of anthropogenic transport.

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Current distribution of Nilgiri grass yellow *Eurema nilgiriensis* Yata (Lepidoptera: Pieridae), with an updated taxonomic key to *Eurema* of Western Ghats, India

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ABSTRACT: *Eurema nilgiriensis* Yata, 1990, the Nilgiri grass yellow, was described from Nilgiris in southern India. There are not many published records of this species since its original description, and it was presumed to be a high-elevation endemic species restricted to its type locality. Based on the external morphology (wing patterns) as well as the male genitalia, the first confirmed records of the species from Agasthyamalais and Kodagu in the southern Western Ghats, is provided here. This report is a significant range extension for the species outside the Nilgiris, its type locality. Ecological data pertaining to this species as well as the field identification key to all known *Eurema* of Western Ghats are also presented.

KEY WORDS: Nilgiri grass yellow, *Eurema*, Agasthyamalais, Kodagu. Western Ghats, rediscovery

INTRODUCTION

The grass yellows or small sulphurs of the genus *Eurema* Hübner, [1819], are relatively small, black-bordered deep lemon-yellow butterflies of open areas with circum-tropical distribution (Corbet and Pendelbury, 1992). They are seen in both the tropical and sub-tropical regions, and some members even inhabit the temperate zones as well (Yata, 1989). They are active in the morning and evening with the noon spent resting on underside of low foliage. Seasonal forms exist and sexual dimorphism is also developed in some species. Males are seen in large numbers in mud-puddling assemblages. Flowers are avidly visited. They occasionally migrate (Yata, 1989). Flight is weak and fluttering. Larval hostplants are from family Fabaceae (Nitin *et al*., 2018) and Rhamnaceae; and as far as it is known, only Rhamnaceae for the *andersoni* subgroup of *Eurema* (Yata, 1991). They are important pollinators and are also considered as pests of some agriculturally important plants (Yata, 1989).

Eurema has eight species in India (Yata, 1989), six of which are recorded from Western Ghats and Nilgiris of peninsular India viz., *Eurema andersoni shimai* Yata & Gaonkar, 1999*, E. blanda silhetana* (Wallace, 1867), *E. brigitta rubella* (Wallace,

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1867), *E. hecabe hecabe* (Linnaeus, 1758), *E. laeta laeta* (Boisduval, 1836) and *E. nilgiriensis* (Yata, 1990) (Evans, 1932; Wynter -Blyth, 1957; Larsen, 1987; Gaonkar, 1996; Kunte et al., 2018). Of these, *Eurema andersoni shimai* and *E. nilgiriensis* are rare as evident from the paucity of published records, but all the other species are common in the state of Kerala (Gaonkar, 1996). There is a single specimen of a male of *E. novopallida* Yata 1992 from south India in the collection of Smithsonian Institution (Washington) (Yata,1992), but this record needs further confirmation (Yata, 1989). The life cycle and flight periods of all the species are known (Kunte *et al.*, 2018), except for *E. nilgiriensis* Yata, 1990.

Following Yata (1991), the *andersoni* complex in *sari* subgroup of *Eurema* is represented by *Eurema andersoni shimai* and *E. nilgiriensis* in Western Ghats. The two taxa were earlier considered to be the same and have been variously treated by different authors under the common name -The One Spot Grass Yellow. *Eurema nilgiriensis* was described by Yata in 1990 from the Nilgiris from specimens in two private collections in Japan (Fig. 1). The species was separated from the very closely related *E. andersoni* based on the consistent external morphological features and the differences in male genitalia (Yata,1990). *Eurema nilgiriensis* was known to be restricted, and endemic, to the Nilgiri hills and there are no confirmed published scientific records after the type description in 1990. But, Yata and Gaonkar (1999) mentioned in a later paper that the species flies sympatrically with *Eurema andersoni shimai* in north and south of Palghat Gap of Western Ghats. Gaonkar (1996) considered that the species is 'Rare' and is seen in Kerala, Tamilnadu and Karnataka. However, there are no specific mention of specific locality details or museum specimens so as to confirm its presence in the Western Ghats proper. The northern and southern most range of this species was still unknown.

Images of duly identified species of *Eurema nilgiriensis* Yata, 1990 based on external morphology is given on http://www.ifoundbutterflies.org/ by Kunte *et al.* (Anonymous, 2018). But this is the first time that the species confirmation made based on male genitalia. The male genitalia is the most important characteristic for determination of *Eurema* species (Yata, 1989). It was in this context, the present study on the genital morphology of *E. nilgiriensis* was undertaken. Basic data on the ecology of this species, notes on its taxonomy, as well as a revised key for field identification of *Eurema* of Western Ghats.

MATERIALS AND METHODS

While documenting butterflies in the Shendurney Wildlife Sanctuary in Kerala during January 2018, a few individuals of *Eurema* were noted in the fringes of a secondary forest near Rosemala in Kollam district. Subsequently, similar individuals were recorded from Sollekolli and Makutta from Kodagu, in Karnataka during April and May 2018 (Fig.1). The butterflies were photographed in the field and images were compared with the type images of *Eurema* from Yata collections (1990) and also with the images of Paratypes from BMNH, London (Fig.2). Earlier in 2013 the corresponding author had sightings of similar morphs of *Eurema* in Thenmala in the Shendurney Wildlife Sanctuary. Two male specimens of similar morphs of *Eurema* were located from Thenmala regionin the insect collections of National Centre for Biological Sciences (NCBS), Bengaluru (Specimens NCBS-BH868 and NCBS-BH869). These specimens, and another from Kodagu (NCBS-AW839), were dissected for the male genitalia to confirm the species.

Taxonomy of *Eurema* follows Yata (1989;1991). The morphological features mentioned refer to the external morphology and coloration unless otherwise specified. The present work is based on three male specimens in NCBS collection and field images of *E. nilgiriensis*. The genitalia were studied by overnight soaking in KOH and dissecting under Stereo Zoom Microscope (HEADZ Model HD81) and preserved in glycerol. Illustrations and photographs of male genitalia were made using a Stereo Zoom Microscope. Nomenclature for genitalic structures follow Yata . (1989)The length of the forewing (FW) - from the wing base to the apex, was also measured.

RESULTS

***Eurema nilgiriensis* Yata, 1990** (Fig. 2- 6)

Specimens studied were from the post-monsoon cold months of December to April, representing the Dry Season Form (DSF) from Agasthyamalais and May-November Early Wet Season Form (WSF).

Material Examined (n=4):

NCBS-BH868: *Eurema nilgiriensis* Yata, 1990, Male, Rosemala, Shendurney Wildlife Sanctuary, Kollam District, Kerala State, India, 20th September 2013 at 150m above M.S.L, collected by NCBS team, Habitation near Secondary forest. Deposited in the Research Collections Facility at the National Center for Biological Sciences (NCBS), Bengaluru India (Fig. 3 A, B).

NCBS-BH869: *Eurema nilgiriensis* Yata, 1990, Male, Kattalapara, Thenmala Reserve Forest, Kollam District, Kerala State, India, 5th October 2013 at 100m above M.S.L, Collected by NCBS team, Forest road near habitation. Deposited in the Research Collections Facility at the National Center for Biological Sciences (NCBS), Bengaluru India (Fig. 3 C, D).

NCBS-AW839: *Eurema nilgiriensis* Yata, 1990, Male, Wet only, Nitin R., Makutta, Kodagu District Karnataka, 12th May 2018, at 700 m above M.S.L Evergreen Forest. Deposited in the Research Collections Facility at the National Center for Biological Sciences (NCBS), Bengaluru, India.

NCBS-AZ862: *Eurema nilgiriensis* Yata, 1990, Female, Dry only, Nitin R. and G. S. Girish Kumar, Sollekolli, Kodagu District, Karnataka, 18th April 2018, at 750m above M.S.L Evergreen Forest. Deposited in the Research Collections Facility at the National Center for Biological Sciences (NCBS), Bengaluru, India (Fig. 3 E, F).

Additional records examined (n=10): Ten male specimens were observed, photographed and studied in the field from Rosemala, Shendurney Wildlife Sanctuary, Kollam District, Kerala State, India, during December 2017 to October 2018, at 100 above M.S.L, from a habitation near Secondary forest, but not collected (Table 1).

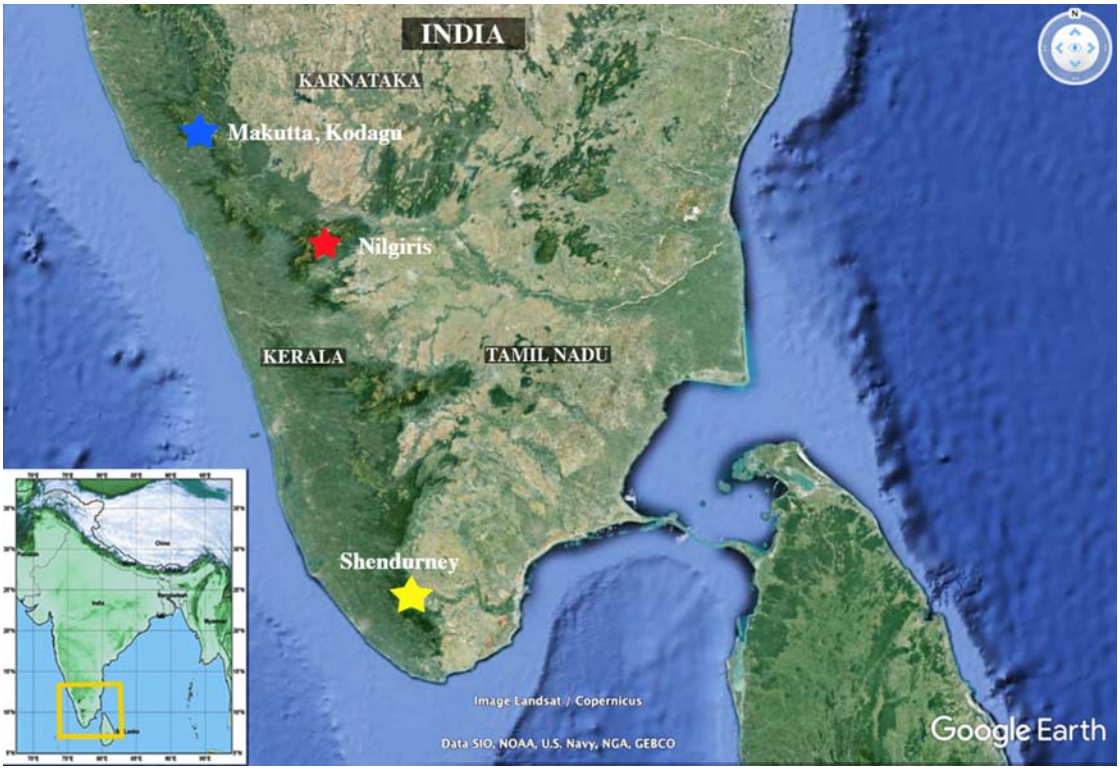

Fig. 1. Map of the study area in Western Ghats of southern India.

Fig. 2. Paratype of *Eurema nilgiriensis* Yata, 1990 (specimen code: BMNH(E) 2002-153).

Diagnosis (Fig. 2 - 6): **Male**

Antennae are chequered black and white, eyes greenish yellow, rest of the head yellow and legs paler yellow.

Underside: The ground color of the wings are yellow with chocolate colored apical patch on forewing and black streaks, chocolate brown patches and rings. *Underside of Forewing* (UnF): Yellow, usually with a well-defined apical chocolate patch occupying 2/5th of the distal spaces four & five, 4/5th of spaces 6 & 7 and middle 2/3rd of space 8. This patch produced outwardly as a dark, almost black triangular patch, towards the middle of space 3. A single '3' shaped mid-cellular spot present. This chocolate brown apical patch is very variable from a well-defined one to a barely traceable one depending on the season. The disco-cellular spot appears as a ring like spot occupying 3/4th of the disco-cellular vein. Male brand: pale grey, narrow and ending well before origin of vein 2. The faint reflection of the markings and excavations in space 2, 3 visible on UnF. Small triangular sub-marginal end-vein spots are black and they join to form a very thin but well defined sub-marginal line. Cilia blackish-brown. *Underside of hindwing* (UnH): Base of space 7 without a minute black spot. Similar to the FW, the full series of small triangular sub-marginal end-vein spots are black but they do not join to form sub-marginal line. Post-discal spots are shaped like lunules and are formed by black dusting and are contiguous in spaces 4,5 and 6. Lunule in space 2 shifted out and not in line with that in 2 and 4. Lunule in space 7 in line with the disco-cellular ring spot. The two basal lunules not in line in space 1a and 1b. One sub-basal ring shaped spot present in each of the spaces one above and one below the cell. The sub-basal and the discodal-cell spot or ring at the base of the cell not in line, the later being pushed slightly outwards.

*Upperside of Forewing (*UpF): The general color is yellow costa bordered in thin but well defined black border. Apical triangular patch and termen thickly bordered in black. The yellow in space 2 more excavating into the black border than in space 3. The black apical patch forms an obtuse angle in the inner border in space 4. The black border is produced along the border of the dorsum for a short distance; hence, the yellow margin is concave internally in space 1b. *Upperside of Hindwing* (UpH): Yellow with a very thin black border along the termen, which is slightly produced along each vein for a very short distance.

Genitalia (Fig. 4, 5): The genus *Eurema* has multiple spine-like processes on the medial wall of the male valva (Fig. 4 D, 5A). The structure of *E. nilgiriensis* is in general agreement to the *Eurema sari–andersoni* group armature. Process 1 (P1) the process near the middle of the ventral margin of costa-ampulla of the valva is short as in all *Terias* subgenus. P2, a process beyond the middle of the dorsal margin of the valva, is developed as a prominent hump, clearly visible in the lateral view

Fig. 3. Images of specimens of *Eurema nilgiriensis* Yata,1990: NCBS-BH868, male, wet season form (A:Un & B:Up), NCBS-BH869, male, wet season form (C:Un & D:Up), NCBS-AZ862, female, dry season form(E: Un & F:Up).

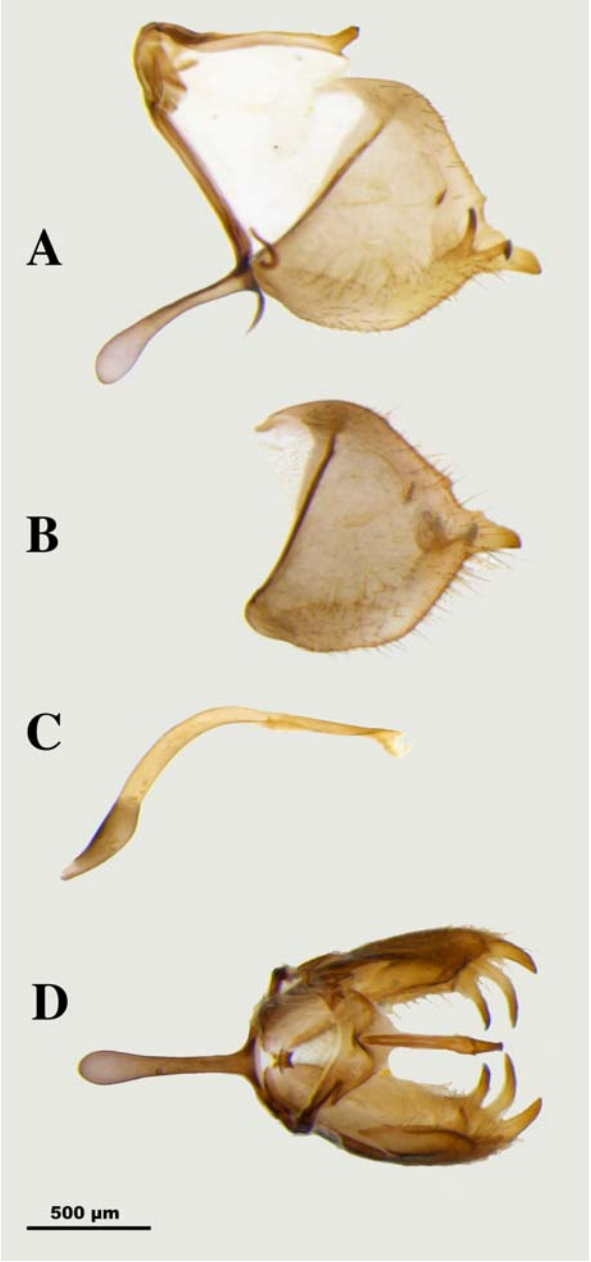

Fig. 4. Image of Male genitalia of *Eurema ni-lgiriensis* Yata, 1990 (NCBS-AW839)

(Fig. 4B, 5C). The P3 or the tip of the valva has a curved tip inwards. There is another small hump like process between P2 and P3, on the dorsal margin, visible in lateral view (Fig. 4A, 5D). The harpe of the valva bears the P4 and P5 arising as a bifurcated process with tips curved ventro-medially. The aediagus is as in the type specimen with a uniform curve with the dorsal convexity (Fig. 4C, 5B). The uncal projection is shaped like a snakehead

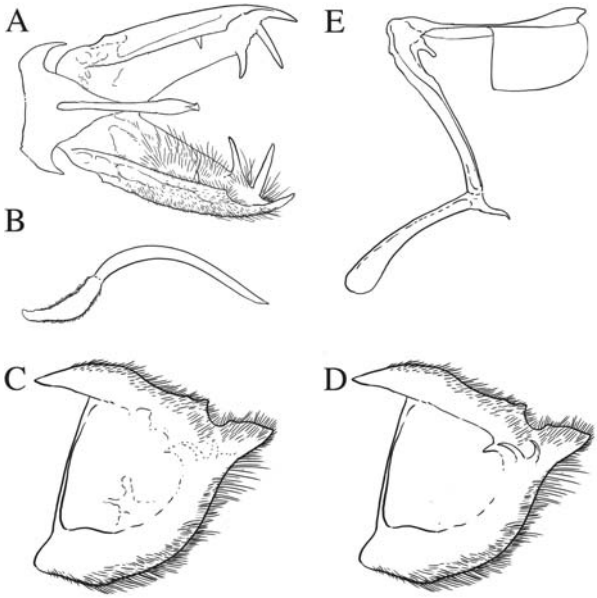

Fig. 5. Illustrations of male genitalia of *Eurema nilgiriensis* Yata, 1990, based on NCBS-BH868 and NCBS BH869

Fig. 6. Field image of *Eurema nilgiriensis* Yata, 1990 from Shendurney Wildlife Sanctuary, Kerala

(Fig. 4A, 5E) and not triangular as in *Eurema andersoni shimai* Yata and Gaonkar, 1999. Thus the male genitalia is in perfect agreement to that of the Type specimen in Yata (1990).

Female: Coloration similar to males, except that the UpF black border is almost right angled at vein 4.

Measurements: Male*:* FW 1.8-2.0 cm (n=3), Female: 2.2 cm (n=1)

Ecological Notes: In contrast to other *Eurema* in south India, the species from *andersoni* subgroup - *E.andersoni shimai* and *E. nilgiriensis* are forest insects and are seen flying amongst thick evergreen and secondary forests. According to Yata and Gaonkar (1999), both apparently fly together in the high elevations. Interestingly, all our records of *E. nilgiriensis* are from below 300m in the Agasthyamalais and below 750m in Kodagu as far its is known, well below the Shola-Grasslands (>1800m). The species was found in a habitation near a secondary forest at 100-150m elevations in Rosemala in Shendurney Wildlife Sanctuary during December 2017 to January 2018. In Kodagu the species was recorded at an elevation of 700-750m in an evergreen forest in April and May 2018. The butterflies were active from 9 am and were seen flying very low within three feet from ground

Table 1. Details of specimens/photographs of *Eurema nilgiriensis* Yata, 1990 examined

No	Locality	Elevation	Collected	Sex	Date	Collector/Photographer
1.	Rosemala, Shendurney, Kerala	150m	Yes	Male	September 2013	NCBS Team
2.	Kattalapara, Thenmala, Kerala	100m	Yes	Male	October 2013	NCBS Team
3.	Kattalapara, Shendurney, Kerala	110m	No	Unsexed	December 2017	Kalesh Sadasivan
4.	Rosemala, Shendurney, Kerala	200m	No	Unsexed	December 2017	Kalesh Sadasivan
5.	Rosemala,Shendurney, Kerala	200m	No	Unsexed	January 2018	Kalesh Sadasivan
6.	Kattalapara Shendurney, Kerala	100m	No	Unsexed	January 2018	Kalesh Sadasivan
7.	Kattalapara Shendurney, Kerala	200m	No	Unsexed	January 2018	Kalesh Sadasivan
8.	Kattalapara Shendurney, Kerala	150m	No	Unsexed	March 2018	Kalesh Sadasivan
9.	Sollekolli, Kodagu, Karnataka	750m	Yes	Female	April 2018	Nitin.R
10.	Makutta, Kodagu, Karnataka	700m	Yes	Male	May 2018	Nitin.R & G. S. Girish Kumar
11.	Kattalapara Shendurney, Kerala	110m	No	Unsexed	October 2018	Kalesh Sadasivan
12.	Kattalapara Shendurney, Kerala	300m	No	Unsexed	October 2018	Kalesh Sadasivan
13.	Kattalapara Shendurney, Kerala	110m	No	Unsexed	October 2018	Kalesh Sadasivan
14.	Rockwood, Shendurney, Kerala	300m	No	Unsexed	November 2018	Kalesh Sadasivan

amongst herbaceous vegetation, in shade, along a village path. In a transect at Shendurney Wildlife Sanctuary, of 500m of half an hour duration we could find three individuals in a path leading to a habitation bordering a lowland secondary forest. All of them were avidly nectaring on low-growing herbs like *Rungia* (Fig. 6). If disturbed they flew into the relatively thicker undergrowth of the jungle. Males were seen occasionally on damp patches and on dead millipedes on road-kills in mixed assemblages, but always singly and never in swarms, in contrast to some other *Eurema*. Females were seen ovipositing on Bombay Smythea *Ventilago bombaiensis* Dals. (Rhamnaceae), a common woody climber seen in the undergrowth of evergreen forests, riparian tracts and Myristica swamps.

DISCUSSION

The Nilgiri grass yellow *E. nilgiriensis* was presumed to be restricted to the Nilgiri Mountains of southern India. Now confirmed its presence in Shendurney region of Agasthyamalais and Kodagu in the Western Ghats proper, based on external morphology and structural details of male genitalia. This is a significant range extension for the species into the southern Western Ghats, outside the type locality, Kodagu being the known northernmost and Agasthyamalais being the known southernmost localities where the species has now been confirmed. Unlike reported in Yata and Gaonkar (1999) the species is found at low elevations (<200m) and mid-elevations (<750m) in suitable habitats on the western slopes of the southern Western Ghats. The habitat of *E. nilgiriensis* is lowland evergreen, semi-evergreen, and Myristica Swamp forests in Agasthyamalais and low- and mid-elevation evergreen forests in Kodagu. Thus it may be reasonably presumed the species was probably collected from a low- to mid-elevation habitat from western Nilgiris and is not a high-elevation Shola-Grassland species as projected in literature (Yata, 1991; Yata and Gaonkar, 1999). In Agasthyamalais the species is not sympatric with *E. andersoni shimai* at least in the low elevations, but in Kodagu they fly together in the mid-elevations. Male genitalia dissection should be done for species confirmation in case of any ambiguity or confusion with *E. andersoni shimai*, as the latter may have equal excavations on spaces 2 and 3 UpF. With respect to the legal protection and conservation status, *E. nilgiriensis* is not listed under Indian Wildlife (Protection) Act, 1972 or Red-listed by IUCN hence a critical assessment is warranted, as is for all the butterfly taxa in the Western Ghats. The extent of variation in coloration, genital morphology and the details of early stages are in preparation and shall be published elsewhere. The status of this species seems to be locally common in suitable habitats. A simple field identification key for *Eurema* of Western Ghats is provided below which can be complimented with genitalia dissection of males, which is confirmatory in case of any taxonomic confusion.

Key to the grass yellows *Eurema* Hübner, (1819) of Western Ghats

The following is a key to the known *Eurema* of Western Ghats based on external morphology modified from Evans (1932) and Yata (1989).

1. UnH Post-discal spots in spaces 4, 5 fused to form a band.....*Eurema* Hübner (1819)

1) Post-discal spots joined to form parallel bands.....…*Eurema laeta* (Boisduval, 1836)

2) Post-discal spots not forming parallel bands.....*Eurema brigitta* (Stoll, 1780)

2. UnH Post-discal spots in spaces 4 and 5 always separate….....….*Terias* Swainson, 1758

1) UnF with one spot in cell, UnH base of space 7 without a minute black spot

a) UpF space in 3 deeply excavated than 2 .....*Eurema andersoni* (Moore, 1886)

b) UpF space in 2 deeply excavated than 3 ...….....*Eurema nilgiriensis* Yata, 1990

2) UnF with 2 or more spots in cell, of which one or all may be absent occasionally

a) UnF with 2 cell spots, UnH with base of 7 no black spot ...*Eurema hecabe* (Linnaeus, 1758)

b) UnF with 3 cell spots, UnH with base of 7 with a black spot..... .....*Eurema blanda* Boisduval, 1836

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A new subgenus and three new species of stingless bees (Hymenoptera: Apidae: Apinae: Meliponini) from India

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ABSTRACT: A new subgenus of stingless bees, *Flavotetragonula* Shanas, **subgen. n**. is established and three new species, *Tetragonula* (*Flavotetragonula*) *calophyllae* Shanas and Faseeh, **n. sp.**, *Tetragonula* (*Tetragonula*) *perlucipinnae* Faseeh and Shanas, **n. sp.** and *Tetragonula* (*Tetragonula*) *travancorica* Shanas and Faseeh, **n. sp.** are described from southern India, based on workers. It is established that *T. (Tetragonula) iridipennis* (Smith, 1854) does not occur in India. The most widespread species in peninsular India is *Tetragonula* (*Tetragonula*) *travancorica* Shanas and Faseeh, **n. sp.** Keys to the subgenera of *Tetragonula* Moure, 1961 and species of *Flavotetragonula* and *Tetragonula* of the Indian subcontinent are provided. Additional information on the geographic range of the north Indian species *T. ruficornis* Smith (1870) is given. The descriptions of the species are supplemented with the characters of foreleg and hind wing.

KEY WORDS: *Flavotetragonula*, *Tetragonula*, systematics, new subgenus, new species

INTRODUCTION

Stingless bees are important pollinators in the tropics. They are more adapted to varying climatic conditions compared to other pollinators such as honey bees and bumble bees. Hence, they are promising candidates for crop production in the tropics. Among stingless bees, *Tetragonula* Moure, 1961 is the most complex genus, with 31 valid species worldwide (Engel *et al.,* 2017; Rasmussen *et al.,* 2017). The main difficulty in differentiating species of *Tetragonula* is the perceived absence of reliable structural characters in workers. Consequently, the classification mostly relied on size, body proportions, coloration and pilosity, which makes the identification of individual specimens difficult or often impossible (Sakagami, 1978).

More than one hundred years ago, four names were proposed for four very similar specimens of *Tetragonula* from India and Sri Lanka (Rasmussen, 2013). Schwarz (1939) recognized *T. iridipennis* var. *iridipennis* as a very widespread form, extending from Ceylon (Sri Lanka) to Solomon Islands. Moure (1961) believed that, *Trigona iridipennis* is synonymous with *Trigona praeterita* Walker, 1860 from Sri Lanka and *Trigona ruficornis* Smith, 1870 from northern

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India. Critical study by Sakagami (1978) redefined *T. iridipennis* as confined to India and Sri Lanka.

Key to species of *Tetragonula* was provided by Bingham (1897), Schwarz (1939) and Sakagami (1978). However, these keys are not reliable (Rasmussen, 2013). Rasmussen provided a catalogue (Rasmussen, 2008) and a key to the workers of the "*iridipennis*" species group of the Indian subcontinent (Rasmussen, 2013). He tabulated the morphometric data based on the primary type specimens and differentiated four primary types viz., *Tetragonula iridipennis*, *T. praeterita*, *T. ruficornis* and *T. bengalensis*. The present study, although limited in geographic coverage, attempts to further streamline the taxonomy of *Tetragonula* of the Indian subcontinent.

MATERIALS AND METHODS

The study is based on an extensive collection of stingless bees in south India. Specimens were collected directly from live colonies and preserved in 98-100% ethyl alcohol. Permanent microscope slides of wings and legs were prepared. Legs were macerated in 10% KOH, washed in distilled water and passed through ethyl alcohol series (70-100 %) and then stained with acid fuchsin. The specimens were then dipped in clove oil and mounted in DPX. Microscope slides of wings were prepared without KOH treatment or staining. Images were processed using CombineZP, Zerene stacker and Adobe Photoshop. Species identifications were confirmed using morphological characters and published records. Morphological terminology (Figs. 1-3) is adapted and modified from Engel (2001), Huber and Sharkey (1993), Mason, (1986), Michener (2007) and Engel *et al.* (2018).

The characters of wings, especially the curvature of the median vein of hind wings, were clearly discernable only when the specimens were slide mounted. The measurements and photographs provided in Rasmussen (2013) alone were used to key out and classify the following three species mentioned in this work: *Tetragonula bengalensis* (Cameron, 1897), *Tetragonula iridipennis* (Smith, 1854) and *Tetragonula praeterita* (Walker, 1860). Key to the species of *Tetragonula* of the Indian subcontinent is partially based on measurements and photographs of holotypes gathered from literature.

The conservation status mentioned in this work is an estimate based on the relative abundance of feral colonies and the colonies maintained by beekeepers in Kerala. The species are categorised as per annotation provided in the IUCN Red List Categories and Criteria (IUCN, 2019). The abbreviations used in this work are as follows: F3 - Length of 3rd Flagellomere; HTL - Hind Tibia Length; HW - Head width; IOD - Inter Ocellar Distance; OD - Ocellar diameter; OOD -Ocello Orbital Distance; WL2 - Wing diagonal.

The specimens are currently held in the collections of the Travancore Insect Collection, Department of Agricultural Entomology, Kerala Agricultural University (KAU), Vellayani, Thiruvananthapuram. The holotype of the new species will be permanently deposited in the National Pusa Collection, Indian Agricultural Research Institute (NPC) and the paratypes will be deposited in the Zoological Survey of India, Kolkata (ZSI) and the British Museum of Natural History (BMNH), London (UK).

RESULTS

SYSTEMATICS

Genus ***Tetragonula*** Moure, 1961

Flavotetragonula Shanas, **new subgenus**

LSID urn:lsid:zoobank.org:act:D68E8948-E4DC-4D84-BBF9-9B3112EB1CCC

Type species: *Tetragonula* (*Flavotetragonula*) *calophyllae* Shanas and Faseeh, new species.

Diagnosis: *Flavotetragonula* Shanas, **n. subgen.** can be distinguished from the related subgenus *Tetragonula* Moure, 1961 based on a combination of the following four characters: (i) the curvature of the median vein of hind wings (Fig. 2, 3) which is weakly curved and never bent (Fig.3) in *Flavotetragonula* **n. subgenus**, whereas it is distinctly bent or strongly curved in the nominotypical subgenus (Fig. 2); (ii) the absence or presence of unculus subapically on vein 4Rs of the forewing (Fig. 4B), (iii) presence of area beneath

costal notch without microtrichia (Fig. 5A), and (iv) presence or absence of microtrichia along apical margin of forewing (Fig. 5C).

Remarks: The weakly curverd vein M on hindwing, which is never bent, is the only robust character which differentiates *Flavotetragonula* Shanas **n. subgen**. from the nominotypical subgenus of the Indian subcontinent. Unculus here, is defined as the raised pigmented projection at the subapical region of vein 4Rs on the forewing of certain species of *Tetragonula*. Unculus is mostly absent in *Flavotetragonula* Shanas, **subgen. n.**

Etymology: The subgeneric name is derived from *flavus* in Latin for yellow.

The new subgenus *Flavotetragonula* is proposed to contain the following three species.

1. *Tetragonula* (*Flavotetragonula*) *calophyllae* Shanas and Faseeh, new species.
2. *Tetragonula* (*Flavotetragonula*) *gressitti* (Sakagami, 1978)
3. *Tetragonula* (*Flavotetragonula*) *praeterita* (Walker, 1860)

Key to the subgenera of *Tetragonula* Moure, 1961

1. Scape shorter than torulocellar distance; about five distal hamuli; posterior contour of metatibia slightly convex, with distal angle subangulate; penicillus usually composed of soft setae (Indomalayan and Australasian) 2

— Scape at least as long as torulocellar distance; six distal hamuli; posterior contour of metatibia distinctly convex and distal angle rounded, almost without angulation; penicillus composed of stiff setae (Sumatra, Kalimantan) ....*Tetragonilla* Moure.

2. Vein M on hindwing distinctly bent (Figs. 2A, 2B) or strongly curved (Fig.2C); Unculus present (Figs. 4B, 7A, 9A) or absent (Fig. 8A) on vein 4Rs of forewing; microtrichia along forewing apical margin present (Fig. 4C); area beneath costal notch with microtrichia (Fig. 4A) ..... *Tetragonula* Moure.

— Vein M on hindwing weakly curved, never bent (Figs. 3A, 3B); Unculus mostly absent (Fig. 5B) or weakly present on vein 4Rs of forewing; microtrichia along forewing apical margin absent (Fig. 5C); area beneath costal notch without microtrichia (Fig. 5A) ....*Flavotetragonula* Shanas, **n. subgen.**

1. *Tetragonula* (*Flavotetragonula*) *calophyllae* Shanas & Faseeh, **new species** (Figs. 6 A-M)

LSID urn:lsid:zoobank.org:act:B6CC2F5D-561A-46C7-B496-4E626798967E

Diagnosis: The new species is characterized by a yellow band on clypeus (Figs. 6F, 6G) and smooth, rotund wing hamuli (Fig. 6A). Two morphs exist, one with clear yellow band on the clypeus and lighter mandibles (Fig. 6F) and another with yellow band discontinuous in the middle and darker mandibles (Fig. 6G). This species has prominent plumose setae on infraepimeron unlike any other species (Fig. 6M).

Remarks: This new species resembles *Tetragonula* (*Tetragonula*) *travancorica* Shanas and Faseeh, **n. sp.**, by most diagnostic characters of the forewings, keirotrichial area in the inner surface of metatibia, curvature of strigillae of probasitarsus and erect dark brown setae on margin of mesoscutellum (Fig. 6H). However, they belong to the subgenera *Flavotetragonula* and *Tetragonula*, respectively, and can be easily differentiated. Yellow band on clypeus is absent in *T. travancorica*, while the same is present in *T. calophyllae*.

Description: Female (worker): Body length 3.4 mm (3.35–3.45 mm); forewing length, including tegula, 4.15 mm (4–4.15 mm); head length from anterior margin of clypeus to summit of vertex, in facial view 1.55 mm (1.52–1.85 mm); head width 1.77 mm (1.58–1.85 mm); length of scape 0.62 mm (0.62-0.64 mm); length of 2nd flagellomere 0.11 mm; length of 3rd flagellomere 0.12 mm; metatibia length 1.54 mm (1.49–1.59 mm); forewing diagonal from base of vein M to base of crossvein r-rs at margin of pterostigma 1.12 mm (1.01–1.12 mm).

Length of compound eye/length of scape ratio 1.9,

inter ocellar distance/ocellar diameter ratio 2.22-2.38. Ocelloorbital distance/interocellar distance >0.5. Interalveolar distance/ alveolar diameter ratio 1.1.

Length / width of head ratio 0.86-1.19, length / width of scape ratio 6.0-6.95, length / width of mandible ratio 3.13-3.33, length / width of 3rd tibia ratio 2.60-3.05, length of basitarsus / head width ratio 0.31-0.39, WL2/HW ratio 0.59-0.69, HTL/HW ratio 0.83-1, HTL/WL2 ratio 1.37-1.48 , IOD/OOD ratio 1-1.73, malar space/F3 ratio 0.36-0.44, interalveolar distance / alveolar diameter ratio 1-1.3, alveolorbital distance/alveolar diameter ratio 1.45-2, IOD/OD ratio 2.22-2.38, length of mesoscutum/width of mesoscutum ratio 0.78-0.85, length of eye/ length of scape ratio 1.85-1.9. Clypeus with concave distal margin. Inner margin of mandible distinctly angulate proximal to middle. Strigillae on probasitarsus not uniformly curved.

Forewing with 2Rs, 1rs-m, 1m-cu, 3M, 4M, 1Cu, 2Cu, 3Cu, and 2cu-a (nebulous traces); wing membrane infuscate, highly fuscous in apical portion of radial cell; pterostigma length/width ratio 3.78 - 5.0; marginal cell narrowly open, Unculus absent on 4Rs; 3M tubular in basal half, then nebulous. Hind wing with 5 rotund hamuli; cubital cell nearly closed by weakly nebulous vein Cu-a; radial cell broadly open, r-sm faintly visible; median vein weakly curved and never bent (Figs. 3, 3A, 3B); proximal part of radial sector strongly nebulous and remaining weakly nebulous.

Metasoma broad, narrower than head; apex pointed, well telescoped into preceding segments; with setae on dorsal segments except on first two; first metasomal segment light brown; distal half of apical segment lighter.

Color: Integument, head black. Compound eyes orange brown. Clypeus black with yellow band apically. Labrum yellow brown. Mandibles golden yellow with black apex in light coloured morph; mandibles darker in darker morph. Ocelli light yellow to red. Scape dorsally dark brown to black, ventrally testaceous. Pedicel dark brown. First flagellomere yellow brown to dark brown dorsally, yellow brown ventrally. Flagellomeres with minute setae and pits, dorsally dark, ventrally testaceous.

Thorax black. Plumose setae on thorax yellow brown, stout setae black. Tegula and wing sclerites dark brown, forewing veins, pterostingma dark brown. Wings hyaline. Trochanter yellow brown. Legs black; except tarsomeres brown, lighter towards apex. Penicillus, setae on tibia dark brown; plumose setae on tibia dull. Arolium black with white apex. Pleuron black with minute punctures. Mesoscutum, mesoscutellum, metanotum black. Propodeum black with punctures.

Pilosity: Head with dense plumose setae. Plumose setae denser below face and sparser on clypeus. Frons covered with sparse plumose setae. Labrum with long, short golden setae. Malar space black, without setae. Fine dull white setae on gena. Setae on vertex dark brown. Setae present on neck.

Setae on tegula dark brown. Mesoscutum with long stout black setae; with plumose setae forming indistinct hair bands. Anterior border of mesoscutem with plumose setae and stout setae. Mesoscutellum with dark stout setae along with yellow brown plumose setae on upper margin and light setae on lower margin. Anterior mesopleuron with plumose setae. Metapleuron with dense silvery setae. Infraepimeron with prominent plumose setae. Trochanter with white long spurs. Foretibia with short white, stout black setae on anterior side, posterior side with lamellate setae. Middle tibia with mixture of white setae, stout long black setae, yellow brown plumose setae. Hind tibia with long black stout setae, outer margin with brown plumose setae, keirotrichea on hind tibia silver white in color. Posterior region of hind basitarsus with yellow brown setae on medial line, basal seraceous area variable, less than half to more than half.

Male: Unknown

Material examined: Holotype: ♀ (worker): INDIA, KERALA, Kumbazha, P. Faseeh coll. 22-X-2017; **Paratypes**: 5 ♀ (worker): Same data as that for Holotype; 10 ♀ (worker): Attingal (nest inside hollow trunk of *Calophyllum inophyllum*), Shanas, S. coll. 21-III-2012; 6 ♀ (worker): Malayam. Shanas coll, 12-V-2016.

Distribution: INDIA (Kerala)

Conservation Status: Endangered (EN)

Remarks: The holotype was designated from type colony maintained by M.K.John, Manakkatumannil, Kumbazha, Pathanamthitta Dist., which had subsequently absconded, as reported by M. K. John. Type material was also collected from John's Beevalley and Anthuriums, Malayam (Thiruvananthapuram dist.) maintained by S. A. John and from a colony in existence for more than 30 years on a tree of *Calophylum inophyllum* near the first authors residence at Attingal.

Etymology: The specific epithet is after the generic name of the endangered tree *Calophyllum inophyllum*, on which the first feral colony was observed.

Note on behavior and biology: The species displays more aggression than the common *T. travancorica* **n. sp.** when the colony is disturbed. Only very few surviving colonies were observed with beekeepers in Kerala. None of the beekeepers could succeed in splitting the colony of *T. calophyllae* **n. sp.** under captivity. Breeding behavior of this species still remains unknown. Their feral colonies are extremely rare in the wild. This species requires immediate attention for conservation.

Key to species of subgenus ***Flavotetragonula*** Shanas, subgen, n. of the Indian Subcontinent (based on workers)

1. Bodylengths less than 3.5mm.....2

— Bodylength greater than 6mm……..... *Tetragonula (Flavotetragonula) gressitti* (Sakagami, 1978)

2. Erect setae on the margin of mesoscutellum dark brown (Fig. 6K); scape 6.45x longer than broad ……. *Tetragonula* (*Flavotetragonula*) *calophyllae* Shanas and Faseeh, **n. sp.**

— Erect setae on the margin of mesoscutellum light brown; scape 7.38x longer than broad …… *Tetragonula* (*Flavotetragonula*) *praeterita* (Walker, 1860)

2. *Tetragonula* (*Tetragonula) perlucipinnae* Faseeh and Shanas, new species (Figs. 7 A-M)

LSID urn:lsid:zoobank.org:act:88182IC5-157C-42D9-B5C2-919A9E9C2937

Diagnosis: The new species can be differentiated from all other species occurring in peninsular india and Sri Lanka by a comparatively more hyaline forewing without vein 2Rs (Fig. 7A); light brown erect setae on the margin of mesoscutellum (Fig. 7G) and uniformly curved strigillae on probasitarsus (Fig. 7F), when slide mounted, and evenly concave inner margin of mandible (Fig. 7M).

Description: Female (worker): Body length 3.25 mm (3.2–3.25 mm); forewing length, including tegula, 3.6 mm (3.4–3.65 mm); head length from anterior margin of clypeus to summit of vertex, in facial view 1.35 mm (1.29–1.39 mm); head width 1.48 mm (1.46–1.62 mm); length of scape 0.58 mm (0.56-0.58 mm); length of 2nd flagellomere 0.12 mm; length of 3rd flagellomere 0.12 mm; meta tibia length 1.41 mm (1.38–1.44 mm); forewing diagonal from base of vein M to base of cross vein r-rs at margin of pterostigma 1.02 mm (0.92–1.02 mm).

Length of compound eye / length of scape ratio 2, inter ocellar distance / ocellar diameter ratio 2.43-2.57. Ocello orbital distance / interocellar distance >0.5. Interalveolar distance / alveolar diameter < or =1. Length/width ratio of head 1.1-1.26; length/width of scape ratio 6.24-7.49; length/width of mandible ratio 2.76-3.0, length/width of pterostigma 3.67-4.57, length/width ratio of 3rd tibia 2.75-3.11, length/width ratio of basitarsus 1.78-2, length of basitarsus / head width ratio 0.31-0.33, WL2/HW ratio 0.57-0.69, HTL/HW ratio 0.87-0.95, HTL/WL2 ratio 1.38-1.53, IOD/OOD ratio 1.55-1.89, malar space / F3 ratio 0.25-0.3, Interalveolar distance / alveolar diameter ratio 0.9-1, alveolorbital distance / alveolar diameter ratio 1.6-1.89, IOD/OD ratio 2.43-2.57, length/width of mesoscutum ratio 0.78-0.85, length of eye/scape length ratio 1.94-2.01.

Distal margin of clypeus straight. Inner margin of mandible evenly concave. Strigillae on probasitarsus uniformly curved. Forewing with 1rs-m, 1m-cu, 3M, 4M, 1Cu, 2Cu, 3Cu, and 2cu-a (nebulous traces); 2Rs absent; wing membrane hyaline, lightly

infuscate in apical portion of radial cell; pterostigma length/width ratio 3.67 - 4.57; marginal cell narrowly open, Unculus present on 4Rs; 3M tubular in basal half, then nebulous. Hind wing with 5 distal hamuli; cubital cell nearly closed by nebulous vein Cu-a; radial cell broadly open; vein r-m faintly visible; median vein distinctly angled (Figs. 7A); radial sector weakly nebulous.

Metasoma slightly flattened, narrower than head, tapering towards apex beyond first two segments.

Color: Head black, except, clypeus red brown. Compound eyes brown. Ocelli yellow brown. Scape dark brown, pedicel dorsally dark brown, ventrally ferruginous. First flagellomere yellow, remaining antennomeres brown dorsally and ferruginous ventrally, with minute setae and pits. Labrum brown. Mandibles amber colored with apical dark border. Malar space light brown. Gena black. Neck light brown.

Mesoscutum black, mesoscutellum light brown. Tegula, wing sclerites brown. Metanotum yellow brown. Pleuron red brown with minute punctures. Costal vein, pterostigma dark brown. Wing hyaline. Legs brown anteriorly, yellow brown posteriorly. Basitarsus brown, lighter towards apex of tarsomeres. Penicillium yellow brown. Arolium, black with white apex.

Propodeum red brown. First abdominal segment light brown, rest dark brown. Apical terga brown. All tergal segments with light border. Last abdominal terga yellow brown.

Pilosity: Labrum with long yellow brown setae and white short setae. Clypeus densely covered with plumose setae, frons sparsely covered with plumose setae, which do not obscure integument. Setae on vertex long, light brown. Gena with simple silvery setae. Neck with white simple setae.

Pronotal knobs with dense white plumose setae. Mesoscutum with bands of plumose setae, intermixed with a few light brown stout setae. Setae on mesoscutellum brown along upper margin, white in lower margin, both intermixed with dull white plumose setae. Pleura with silver white setae. Metapleuron with dense long silvered setae. Anterior portion of mesopleuron with dense plumose setae, posterior part with less branched plumose setae. Infraepimeron with faintly plumose setae. Trochanter with white spurs. Keirotrichea white brown. Foretibia with white setae on anterior side, posterior side with lamellate setae. All setae on antenna comb of fore tibia, clearly visible. Middle tibia with mixture of both white and brown stout hairs along with white plumose hairs. Hindtibia with long stout brown setae, outer margin with white plumose setae. White setae anteriorly on median line of basitarsus. Basal seraceous area more than half length of basitarsus. Abdominal terga with setae except first two.

Male: Unknown

Material examined: Holotype: ♀ (worker): INDIA, KERALA, Ayarote, P. Faseeh, coll. 31-X-2017. **Paratypes**: 8 ♀ (worker): Same data as that for Holotype.

Remarks: The type material was collected from M.J. Beefarm of M.J. Kurian, Ayarote, Kasaragod. It is currently known only from the Type locality. The original 'Type colony' absconded, as reported by M.J. Kurian.

Distribution: INDIA (Kerala: Kasaragod)

Conservation status: Data Deficient (DD)

Etymology: The specific epithet is based on the latin words *perlucidulus* and *pinna*, alludes to the transparent wing.

3. *Tetragonula* (*Tetragonula*) *ruficornis* (Smith, 1870) (Figs. 8 A-G)

Notes on distribution: *Tetragonula* (*Tetragonula*) *ruficornis* is widespread in the north Indian plains, from Varanasi to Punjab. They are particularly well adapted to cold weather and probably this is the only species occurring in Northern Uttar Pradesh, Uttarakand, Haryana, Punjab and Delhi. Feral colonies were observed on trees near parks and undisturbed foreign embassy areas in south Delhi.

Remarks: This species can be easily visually distinguished from others by the presence of yellow tinge on antennae and yellow first abdominal

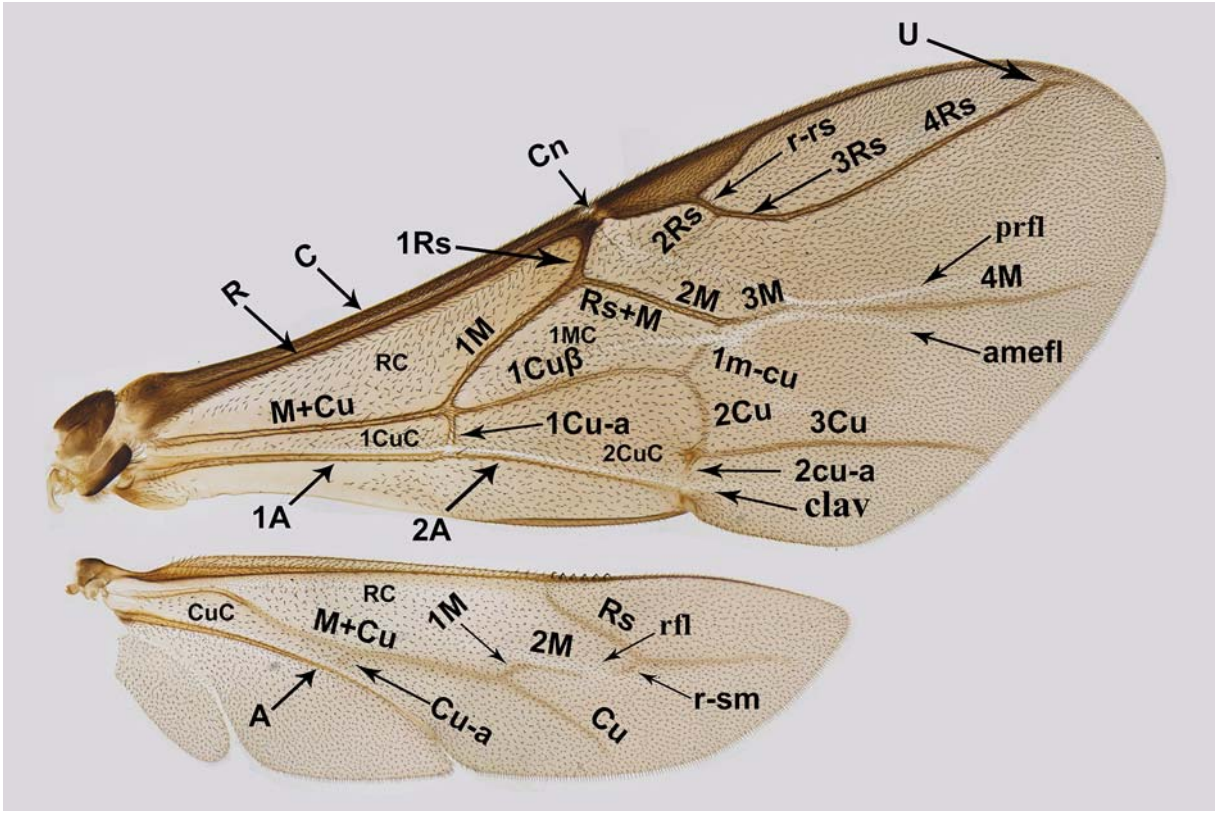

Fig. 1. *Tetragonula* (*Tetragonula*) *travancorica* Shanas and Faseeh, **n. sp.**, fore- and hind wings illustrating wing veins and terminology. A - anal cross vein, amefl, anterior medial; C- Costa; Clav, clava; Cu- Cubitus; Cu-a - Cubito-anal; CuC - Cubital Cell; Cn- Costal notch; M - media; MC - Medial Cell; prfl, posterior radial flexion line; pmefl, posterior medial flexion line; R - radius; RC - Radial Cell; rfl - radial flexion line; Rs - Radial sector; r-sm - radio-sub medial; U - Unculus.

segment (Figs. 8B, 8E). From the photographs given by Preeti *et al.* (2014) and Makkar *et al.* (2018), it is clear that they misidentified *T. ruficornis* as *T. iridipennis*.

Material examined: 10 ♀ (worker): INDIA, DELHI, R. K. Puram, Shanas. S, coll. 25-III-2018; 8 ♀ (worker): VARANASI, IIVR campus, Singh. N., 8-II-2019.

Distribution: INDIA (Uttarpradesh, Uttarakand, Haryana, Punjab, Delhi).

Conservation status: Near threatened (NT).

4. *Tetragonula* (*Tetragonula*) *travancorica* Shanas and Faseeh, new species (Figs. 9 A-J)

LSID urn:lsid:zoobank.org:act:10D7DD1A-D311-4B65-9961-65B6D2F88091

Diagnosis: The new species is distinguished from other Indian species of the subgenus by a strongly nebulous radial vein on the hind wings (Fig. 9A) and dark brown erect setae on the margin of mesoscutellum (Fig. 9C). This species exhibits extreme phenotypic plasticity, however, they can be distinguished from *T. iridipennis* (Smith, 1854) by a comparatively longer (0.11-0.12mm) 2nd antennal flagellomere and other features given in the key to species.

Remarks: These are small to medium sized bees which exhibit varying number of wing hamuli (4 to 6) in symmetric or asymmetric pattern on either wing to the extent of >10 % variation in the population from the normal pattern of 5 hamuli each on both wings. This species is often confused with *T. iridipennis* (Smith, 1854) which is restricted to Sri Lanka. This species is easy to manage and widely multiplied as well as traded by the beekeepers of southern India.

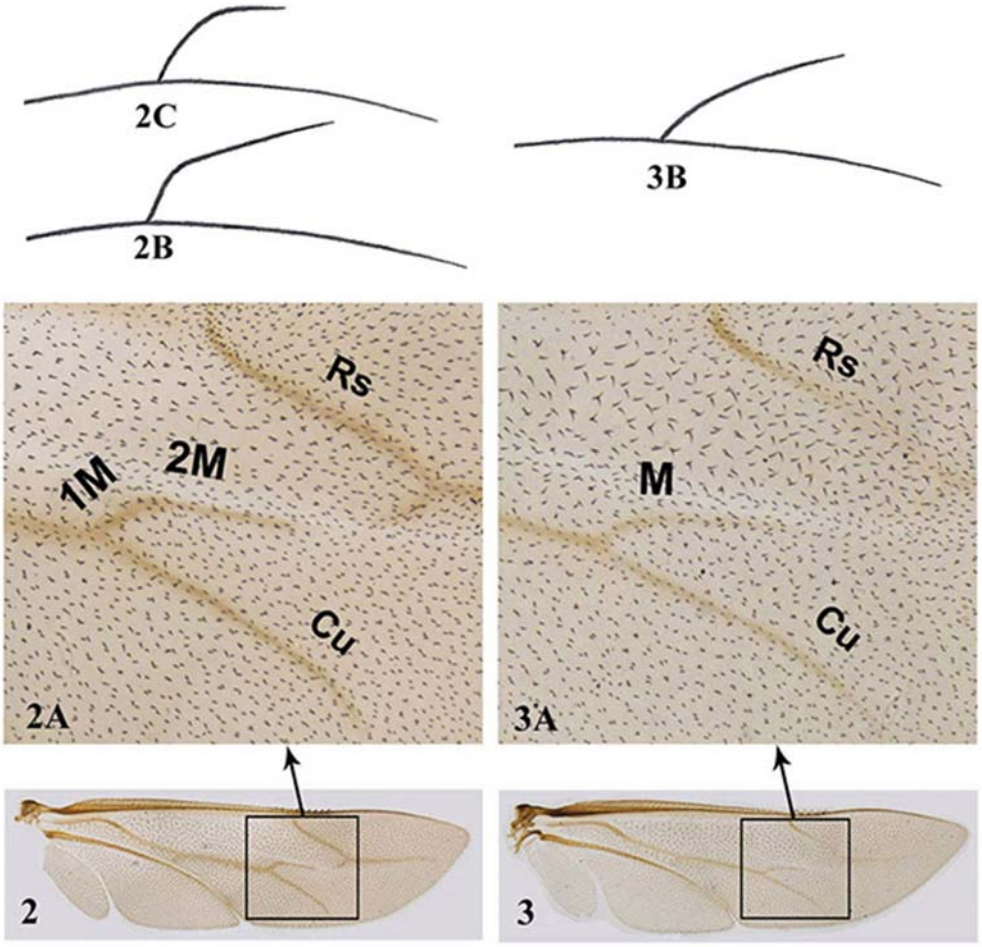

Fig. 2 & 3. Representative characters of the subgenera *Tetragonula* and *Flavotetragonula*. Fig, 2. Hindwing of *Tetragonula* (*Tetragonula*) *travancorica* Shanas and Faseeh, **n. sp.** 2A & 2B. Distinctly bent median vein in *T. travancorica* **n. sp.** ; Fig. 2C. Strongly curved median vein in *T. ruficornis* (Smith, 1870). Fig. 3. Hindwing of *Tetragonula* (*Flavotetragonula*) *calophyllae* Shanas and Faseeh, **n. sp.** 3A & 3B. Weakly curved and never bent median vein in *T. calophyllae* **n. sp.**

Description: Female (worker): Body length 3.55–4.1 mm; forewing length, including tegula 3–4.25 mm; head length 1.29–1.52 mm; head width 1.62–1.82 mm; length of scape 0.53-0.64 mm; length of 2nd flagellomere 0.11-0.12 mm, length of 3rd flagellomere 0.13; metatibia length 1.4–1.9 mm; forewing diagonal from base of vein M to base of crossvein r-rs at margin of pterostigma 0.91–1.2 mm.

Length of compound eye/length of scape ratio 2, inter ocellar distance/ocellar diameter ratio 1.5-2.6. Ocello orbital distance/inter ocellar distance ratio >0.5. interalveolar distance/alveolar diameter ratio 1.l.

Length/width of head ratio 0.82-1.2; length/width of scape ratio 5.14-6.95; length/width of mandible ratio 3.2-4.45; length/width of pterostigma ratio 4-5.7; length/width of 3rd tibia ratio 2.80-3.1, length of basitarsus / head width ratio 0.26-0.32; WL2/ HW ratio 0.57-0.63; HTL/HW ratio 0.86-1.05; HTL/WL2 ratio 1.43-1.67; IOD/OOD ratio 1.5-1.8; malar space/F3 ratio 0.27-0.33; interalveolar distance/alveolar diameter ratio 1.0-1.2; alveolorbital distance/alveolar diameter ratio 1.8-2 ; IOD/OD ratio 1.8-2.5; length /width of mesoscutum ratio 0.83-0.86; length of eye/scape length ratio 1.82-2.0.

Distal margin of clypeus very slightly concave. Inner

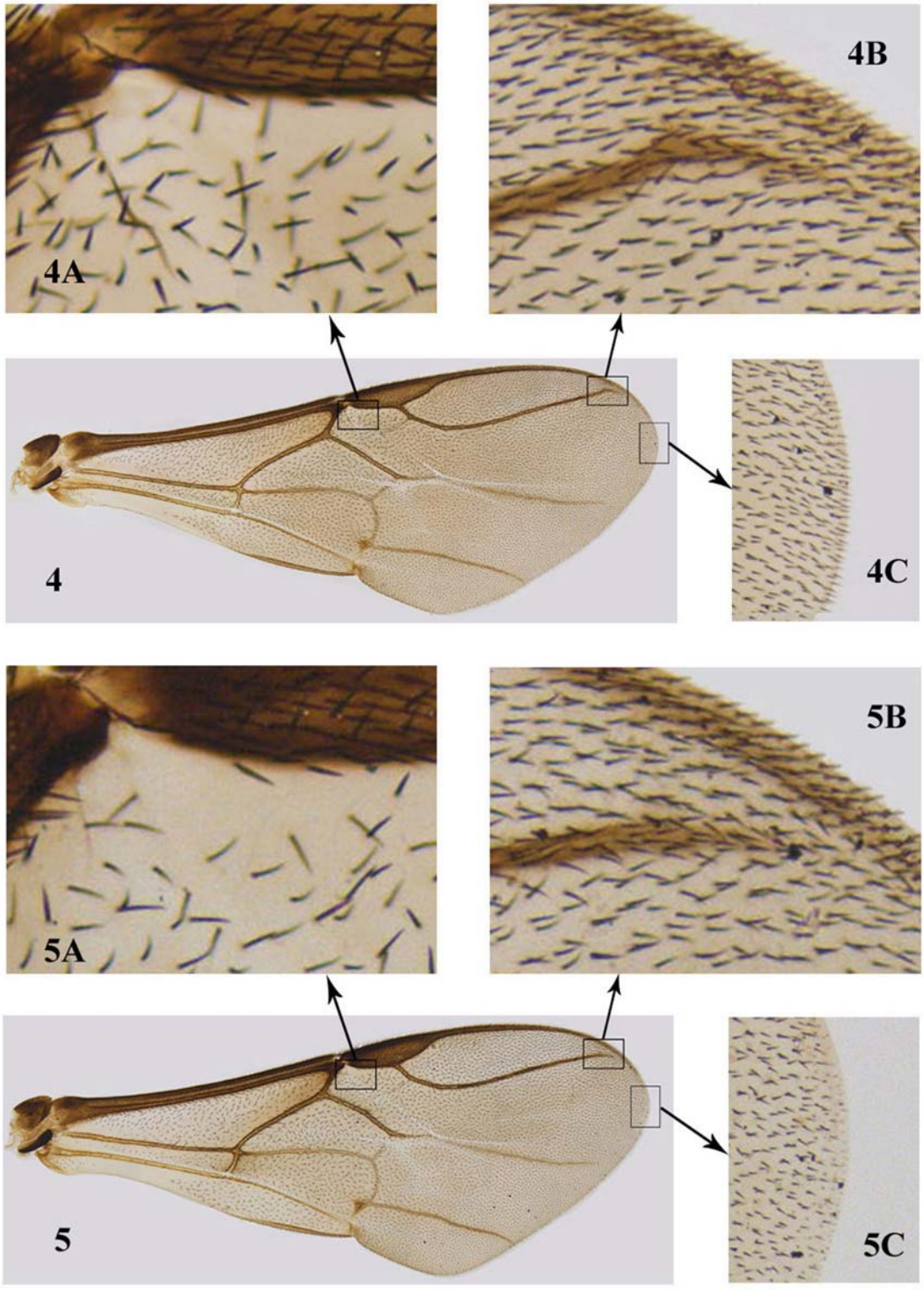

Fig. 4 & 5. Representative characters of the subgenera *Tetragonula* and *Flavotetragonula*. Fig. 4. forewing of *Tetragonula* (*Tetragonula*) *travancorica* **n. sp.** 4A - area beneath costal notch with microtrichia; 4B - unculus; 4C. wing apex; Fig. 5. forewing of *Tetragonula* (*Flavotetragonula*) *calophyllae* **n. sp.** 5A. area beneath costal notch without microtrichia; 5B - unculus. 5C - wing apex.

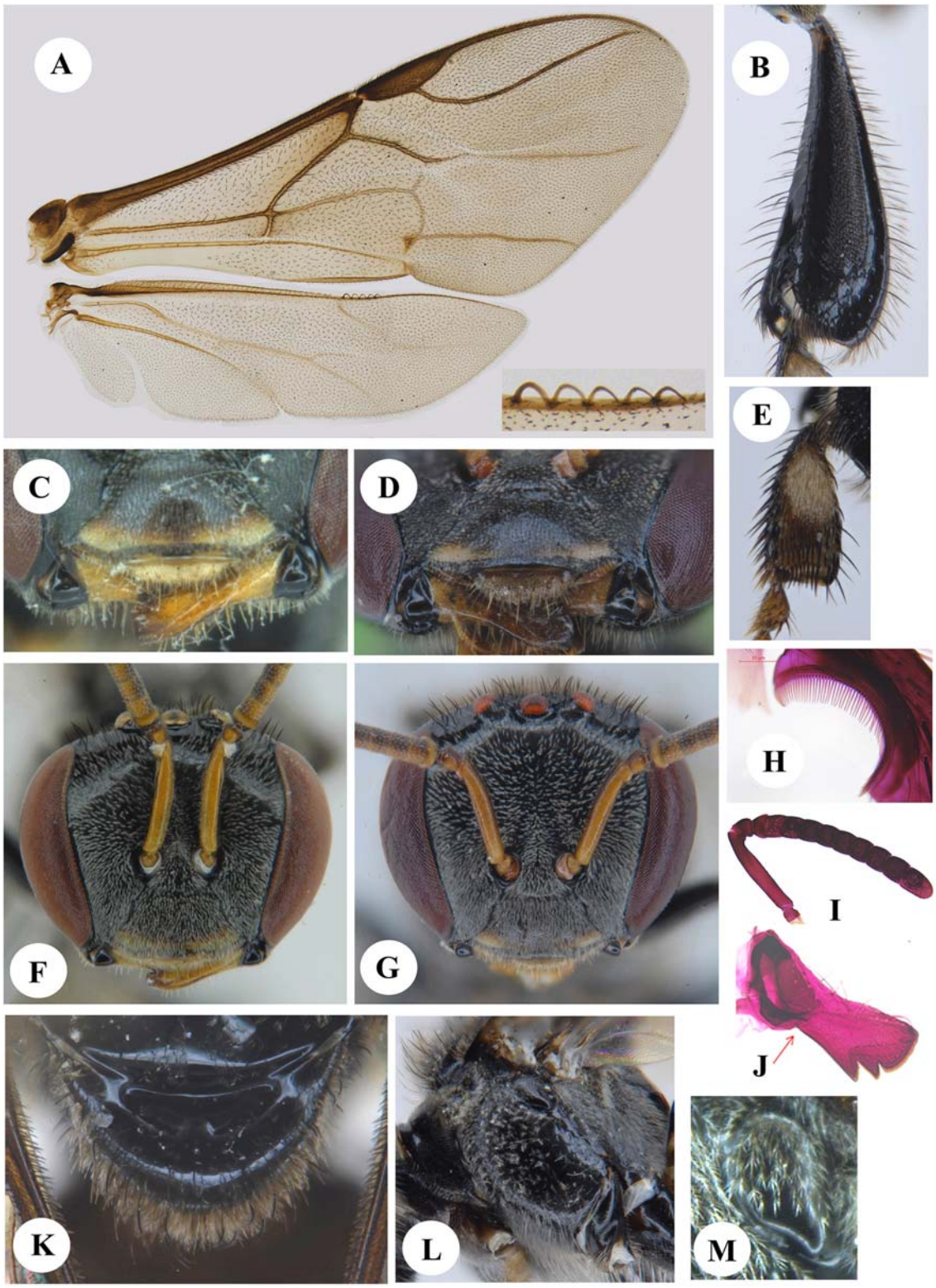

Fig. 6. Workers of *Tetragonula* (*Flavotetragonula*) *calophyllae* **n. sp..** A. forewing, hindwing and hamuli; B. inner view of hind leg; C, D. lower frontal view of clypeus and mandible; E. inner surface of hind basitarsus; F, G. frontal view of head; H. strigillar concavity of the probasitarsus; I. antenna; J. mandible; K. dorsal view of mesoscutellum; L. mesepisternum; M. infraepimeron.

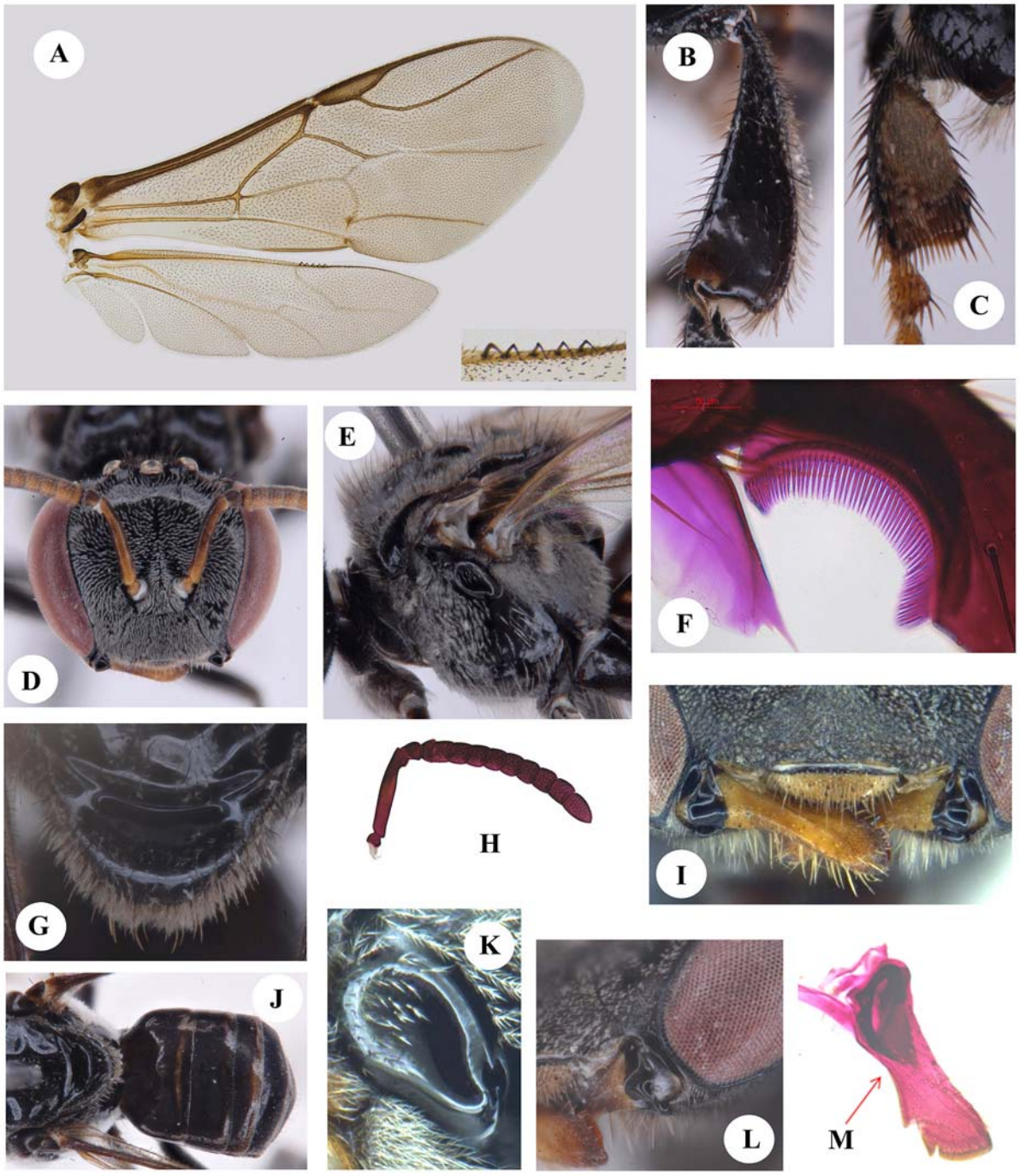

Fig. 7. Workers of *Tetragonula* (*Tetragonula*) *perlucipinnae* Faseeh and Shanas, **n. sp.** A. forewing, hindwing and hamuli; B. outer view of hind leg; C. inner surface of hind basitarsus; D. frontal view of head; E. mesepisternum; F. strigillar concavity of the probasitarsus; G. dorsal view of mesoscutellum; H. antenna; I. lower frontal view of clypeus and mandible; J. dorsal view of metasoma; K. infraepimeron; L. malar area; M. mandible.

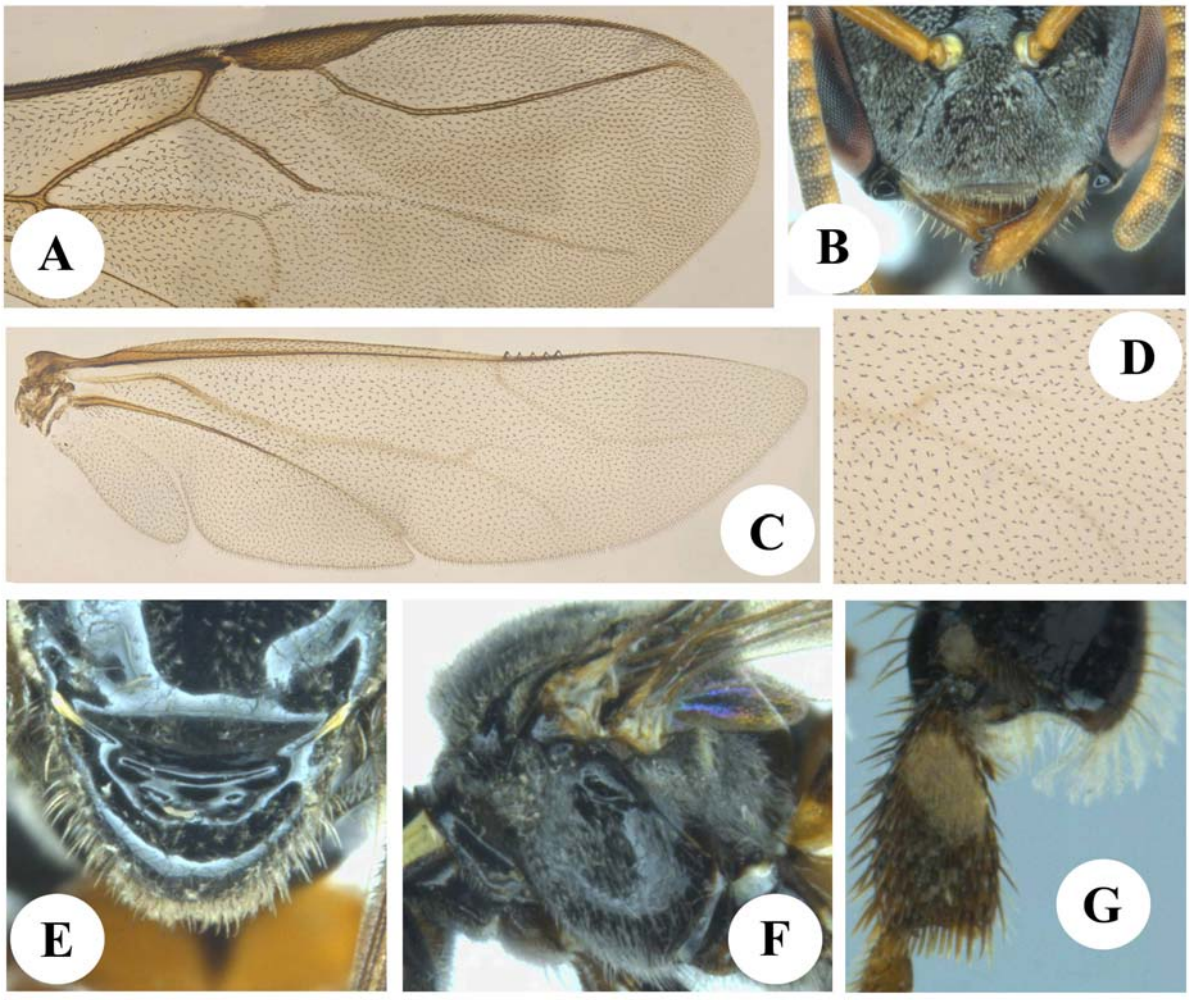

Fig. 8. Workers of *Tetragonula ruficornis* (Smith): A. forewing. B. lower frontal view of head. C. hindwing. D. media of hindwing. E. dorsal view of mesoscutellum F. mesepisternum. G. inner surface of hind basitarsus with sericeous area.

margin of mandible distinctly angulate proximal to middle. Strigillae on probasitarsus not uniformly curved.

Forewing with 2Rs, 1rs-m, 1m-cu, 3M, 4M, 1Cu, 2Cu, 3Cu, and 2cu-a (nebulous traces); wing membrane infuscate (lightly infuscate over most of membrane, darker in apical portion of radial cell); pterostigma length/width ratio 4 - 5.7; marginal cell narrowly open, Unculus present on 4Rs; 3M tubular in basal half, then nebulous. Hind wing with mostly 5 but sometimes variable distal hamuli (4-6) symmetric or asymmetric; radial and cubital cells nearly closed by nebulous veins; median vein distinctly angled (Figs. 2, 2A, 2B); radial vein entire and strongly nebulous. Metasoma broad, pointed at apex and well telescoped in to preceding segments.

Color: Integument, head, neck, gena, clypeus, thorax black. Labrum yellow; mandibles golden brown with black apex; compound eyes red brown; ocelli brown; area between compound eyes and mandible slightly brown; malar area black; antenna brown to dark brown; depression on each flegellomere darker except on first. First flagellomere lighter; scape brown.

Tegula, wing sclerites brown; wing veins, pterostigma brown; wings hyaline. Legs red-dark brown with brown tarsomeres and penicillus; trochanter brown; mesotibial spur yellow. Arolium

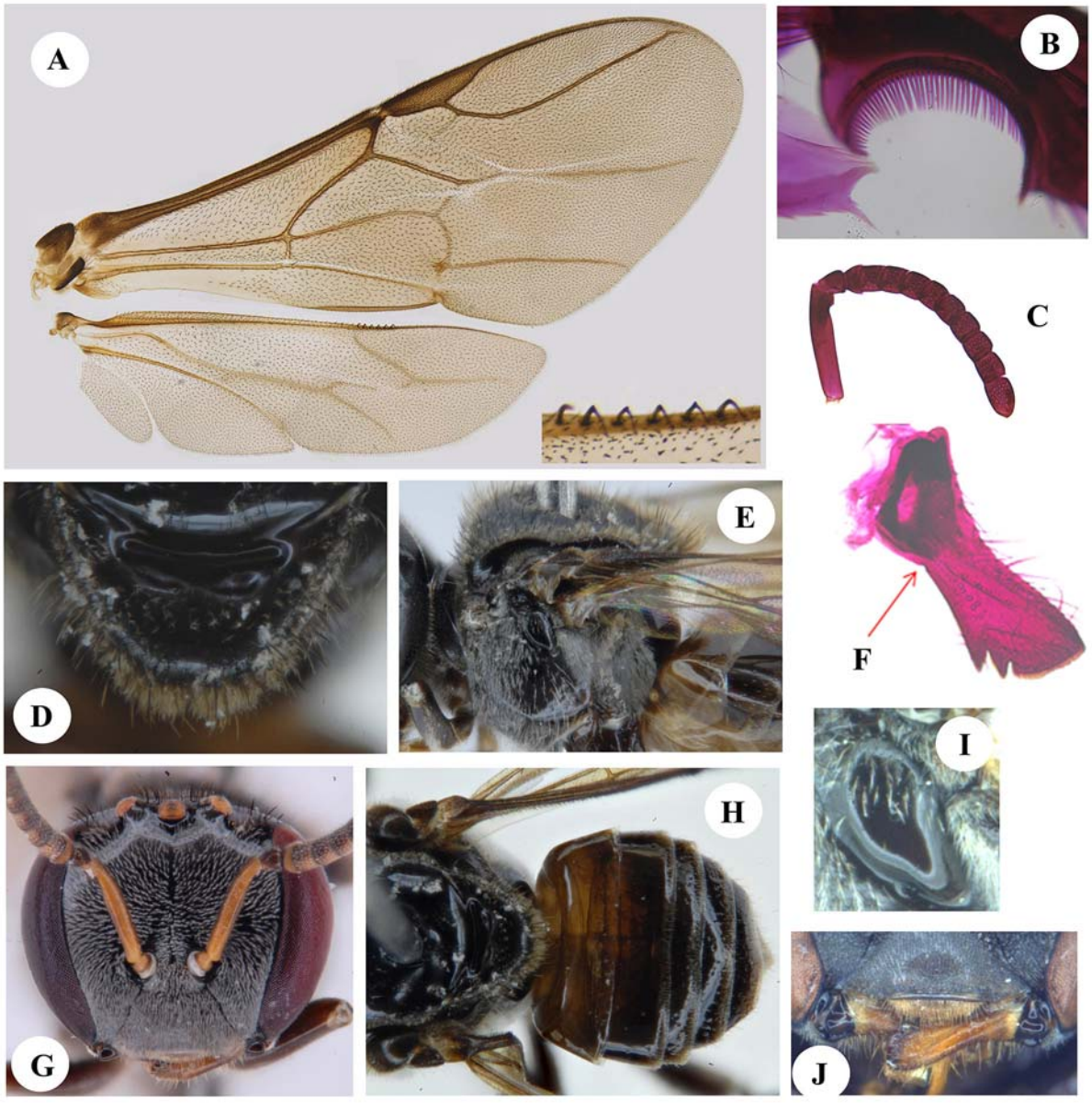

Fig. 9. Workers of *Tetragonula* (*Tetragonula*) *travancorica* Shanas and Faseeh, **n. sp.** A. forewing, hindwing and hamuli; B. strigillar concavity of the probasitarsus; C. antenna; D. dorsal view of mesoscutellum; E. mesepisternum; F. mandible; G. frontal view of head; H. dorsal view of metasoma; I. infraepimeron; J. lower frontal view of clypeus and mandible.

golden brown. Mesoscutellum, propodeum brown to black, metanotum lighter.

Metasoma darker towards apex; first two abdominal segments red brown, remaining ones darker; apical segment yellow to brown at apex, dark brown basally.

Pilosity: Head with dense plumose setae except on vertex. Setae on vertex stout and brown. Labrum with brown to golden brown simple setae. Gena with light brown, fine setae. Neck with simple white setae.

Mesoscutum with white plumose setae. Seta bands very distinct with glabrous interspaces. Mesoscutellum with both dark brown simple and plumose setae. Setae on mesoscutellum and mesosctum are almost similar in size. Metanotum

with short and dull brown setae. Anterior mesopleuron with white plumose setae. Plumose setae at the base of hind wing (metapleuron) is more denser than setae on anterior region. Infraepimeron with faintly plumose setae.

Lamellate setae present on posterior foretibia. Trochanter with white spurs. Femur and tibia with brown simple and white plumose setae. Seraceous area variable, less than half to more than half. Posterior region of hind basitarsus with simple brown setae on medial line. Setae absent on first two abdominal segments.

Males: Unknown

Material examined: Holotype: ♀ (worker): INDIA, KERALA, Kollam, Ambanad Estate. Faseeh P coll, 10-ii-2018; **Paratypes**: 20♀ (worker): Same data as that of Holotype; 20♀ (worker): Vellayani. Shanas, S. coll, 15-II-2015. 10♀ (worker): Attingal, Shanas, S. coll, 27-VI-2016; 12♀ (worker): KARNATAKA, Madikeri, Shanas, S. coll. 05-X-2004; 5♀ (worker): TAMIL NADU, Coimbatore, Shanas, S. coll. 20-V-2007.

Distribution: INDIA (Karnataka, Kerala and Tamil Nadu).

Conservation Status: Least concern (LC)

Etymology: This species is named after the erstwhile kingdom of Travancore.

Key to species of subgenus *Tetragonula* Moure, 1961 of the Indian Subcontinent (based on workers)

1. Vein M on hindwing distinctly bent (Figs. 2A, 2B); Unculus present (Figs. 4B, 7A, 9A) or indistinct on vein 4Rs of forewing. ……...3

— Vein M on hindwing strongly curved (Figs. 2C, 8D); Unculus absent (Figs. 8A) or indistinct on vein 4Rs of forewing ……....2

2. Mesoscutellum 2.82x wider than long; basal sericeous area of hind basitarsus more than half of the length of basitarsus …… .....*T. bengalensis* (Cameron, 1897)

— Mesoscutellum 2.09x wider than long; basal sericeous area of hind basitarsus less than half of the length of basitarsus (Fig. 8G) …… .....*T. ruficornis* (Smith, 1870)

3. Vein 2Rs present on forewings (Fig. 9A); erect setae on margin of mesoscutellum dark brown, distal part of radial cell of forewing infuscate (Fig. 6A)…….....…...…….…….. 4.

— Vein 2Rs absent on forewings (Fig. 7A); erect setae on margin of mesoscutellum light brown (Fig. 7G), distal part of radial cell of forewing very lightly infuscate (Fig. 7A); strigillae of probasitarsus uniformly curved when slide mounted (Fig. 7F) …… ...*T. perlucipinnae* Faseeh and Shanas, **n. sp.**

4. Length of 2nd flagellomere 0.07 mm; width of mesoscutellum (0.57mm) 1.73x length of mesoscutellum (0.33mm); mandible uniformly coloured, without black apical area ....*T. iridipennis* (Smith, 1854)

— Length of 2nd flagellomere (0.11-0.12) mm; width of mesoscutellum (0.74-0.91mm) 2.37-2.67x length of mesoscutellum (0.31-0.34mm); mandible with black apical area …...…….. ...*T. travancorica* Shanas and Faseeh, **n. sp.**

DISCUSSION

The hind wing venation has been consistently neglected by every major worker of the genus (Bingham, Engel, Moure, Rasmussen, Sakagami and Schwarz). The scattered mention to hindwing in most publications are, on the number of hamuli and size. Hind wing venation is vaguely referred to as 'radial and cubital cells closed by nebulous veins' (Engel and Rasmussen, 2017; Rasmussen *et al.*, 2017; Engel *et al.*, 2018). The "*laeviceps*" species group referred to by Sakagami, 1978, Rasmussen, 2010, 2013 (Neotype designated by Rasmussen and Michener, 2010) may contain a complex assemblage of species, mostly falling under the *Tetragonula* Moure, *Flavotetragonula* **n. subgen**., and probably yet another undescribed new subgenus. A comprehensive classification of *Tetragonula*, Moure, 1961 can be attempted only

after proper study of each valid species based on hind wing venation.

The present study introduces three new species of stingless bees to the existing bee fauna of the Indian subcontinent, taking the total species of *Tetragonula* present in the Indian subcontinent to eight and in India to six viz., *Tetragonula (Flavotetragonula) calophyllae* Shanas and Faseeh, **n. sp.**; *Tetragonula (Flavotetragonula) gressitti* (Sakagami, 1978); *Tetragonula (Tetragonula) bengalensis* (Cameron, 1897); *Tetragonula (Tetragonula) perlucipinnae* Faseeh and Shanas, **n. sp.**; *Tetragonula (Tetragonula) ruficornis* (Smith, 1870) and *Tetragonula (Tetragonula) travancorica* Shanas and Faseeh, **n. sp.** The stingless bees of the Indian subcontinent are poorly explored unlike the Neotropical and Indomalayan fauna. Misinterpretation of stingless bee species is widespread in most publications from India, either by mentioning the wrong species name or by referring to species from outside the Indian subcontinent, which are not present in India. The studies conducted by several workers as well as most publications from India (reviewed by Rasmussen, 2013) indicates the presence of *Tetragonula iridipennis,* which probably refers to *T. travancorica* Shanas and Faseeh **n. sp.**, (in South India); *T. ruficornis* (Smith,1870) in the North Indian plains (from Varanasi to Punjab) and many other known and unknown species (elsewhere in India). A thorough and critical review of all publications from India is necessary to assign the proper species name to all published works till date in-order to streamline the research on stingless bees in India.

Stingless bees exhibit varied biology and extremely divergent breeding habits. Proper studies on biology can be conducted only after proper identification of the species involved. Surveys carried out all over India by the first author has revealed the presence of stingless bees in most regions including higher elevations and drier interior regions in India.

Melponine species seem highly diverse in their ecological preferences. The restricted geographic distribution observed among several species in the group may be attributed to their possible narrow range of temperature and floral preference. They are most speciose in the Indomalayan region where, several known and unknown species are probably facing the threat of extinction due to climate change. In India (except north east), several Meliponine species (described and undescribed), well adapted to harsh drier environment, do not seem to face an immediate threat due to climate change. Nevertheless, their distribution range may have been severely restricted due to landscape changes, burgeoning human population and lack of awareness among the general population regarding the identity of meliponines and their importance as pollinators. Transnational collaborative research, focused on systematics, ecology and biology of the species is essential for conservation and sustainable geographic re-deployment of these enigmatic pollinators.

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Franklinothrips vespiformis Crawford (Thysanoptera: Aeolothripidae), a potential predator of the tea thrips, *Scirtothrips bispinosus* Bagnall in south Indian tea plantations

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ABSTRACT: During the surveys carried out for natural enemies of *Scirtothrips bispinosus* Bagnall in tea plantations, the predatory thrips *Franklinothrips vespiformis* Crawford was found preying on tea thrips in High ranges, Nilgiris and Central Travancore regions of south India. The life history and predatory potential of *F. vespiformis* were studied in the laboratory by providing different life stages of *S. bispinosus* as feed. Studies on life history revealed that *F. vespiformis* had six life stages with a greater potential for population increase at 25 °C. Adult stages of *F. vespiformis*, consumed more number of thrips than the larval instars. However, per day consumption was more in second instar larva than adult and first instar. All the active life stages of *F. vespiformis* except the non-feeding pupa preferred mostly first instar larvae for feeding followed by the second instar. Field observations revealed that increase in predator population coincided with the population increase of prey species. The results of the present study indicate *F. vespiformis* as an efficient predator against *S. bispinosus* and therefore it could be explored as a potential biocontrol agent in the management of tea thrips.

KEY WORDS: *Franklinothrips vespiformis, Scirtothrips bispinosus,* tea thrips, life table.

INTRODUCTION

Scirtothrips bispinosus Bagnall (Thysanoptera: Thripidae) is endemic to south India and unlike the polyphagous *S. dorsalis,* it has been reported only on tea and coffee plants (Mound and Palmer, 1981). Its infestation leads not only to crop loss but also to the deterioration of quality of processed tea. Although the chemical control of this pest is possible, continuous use of chemicals may result in the development of resistance against pesticides and also leads to residue problems. In natural tea ecosystem, predatory arthropods play a prominent role in determining the numbers of plant-feeding insects under natural conditions. In view of this, a detailed survey was carried out in the tea plantations of south India to explore the natural enemies of tea thrips *S. bispinosus*. The survey revealed the presence of seven species of natural enemies among which the predatory thrips, *Franklinothrips vespiformis* was found prominent as a predator on tea thrips in high ranges, Nilgiris and Central Travancore regions of south India. The present paper discusses in detail about the life history, population dynamics and predatory potential of *F. vespiformis* on tea thrips.

* Author for correspondence

MATERIALS AND METHODS

Survey on natural enemies

Surveys were carried out between 2007 and 2009 in all the major tea growing areas of southern India viz., the Anamallais (Coimbatore Dist., Tamil Nadu), Ooty, Coonoor, Kotagiri and Gudalur (The Nilgiris, Tamil Nadu), Vandiperiyar, Peermade and Munnar (Idukki Dist., Kerala), Nelliampathy (Palghat Dist., Kerala) and Meppadi (Wayanad Dist., Kerala). Both organic and conventional tea areas were explored for the presence of natural enemies.

Studies on the life history of *F. vespiformis*

Adults and larvae of *F. vespiformis* collected from tea fields were reared in large glass containers (15 cm dia. x 20 cm depth) by providing different life stages of *S. bispinosus* as feed. The females of *F. vespiformis* collected from this stock colony were introduced individually into Plexiglas boxes (8 cm dia. x 7 cm depth) containing thrips infested tea leaves placed on moist cotton. The number of eggs laid per female during the first five days of oviposition period was counted and observed at eight hours intervals to record the eclosion percentage. Newly emerged larvae were individually transferred onto thrips infested tea leaf (5 cm x 5 cm) placed on wet cotton and each box was covered with a transparent muslin cloth. These boxes were kept at environmental growth chamber at 25±2ºC, 75±5% of relative humidity (RH) and with a photoperiod of 16 h of light and 8 hours dark to study the developmental duration. When adults emerged the females were transferred to freshly infested tea leaf at every 24 h until the female died to record the data on fecundity, duration of incubation, periods of pre-oviposition, oviposition and post-oviposition and longevity of adults using binocular stereo microscope. Life tables were constructed as per the method of Birch (1948) and Atwal and Bains (1974).

Studies on prey population Vs predator density

For exploring the prey and predator populations, a study was carried out in the UPASI experimental farm, Coonoor, The Nilgiris between 2007 and 2009. A second year tea field planted with tea clone UPASI-9 (B/6/61) was selected for the present study. The experimental area consisted of four plots each of 100 bushes. This field has not received any pesticide application during the study period. Population density of both nymphs and adults of *S.bispinosus* and *F. vespiformis* were assessed at fortnightly intervals by randomly collecting 100 shoots (3 leaves and a bud) from the plucking table, below the plucking table, and side branches. The number of prey and predators were counted and recorded in the field using hand lens.

Studies on predatory potential

Predatory efficiency (No choice feeding)

Predatory efficiency of individual life stage of *F. vespiformis* was studied in the laboratory by releasing 100 numbers of individual life stages of *S. bispinosus* into the leaf cup. Here, no choice had been given to the predator to choose its prey stage.

Prey stage preference (Free choice feeding)

Prey stage preference of individual life stage of *F. vespiformis* was studied by releasing all life stages (50 numbers each) of *S. bispinosus* in a single leaf cup. Here the predator had the option to choose its prey stage for consumption.

In both the experiments the leaf cup was prepared by placing leaf discs of approximately 5 cm^2 on agar substrate (0.5%, 15 mm thick) in a plastic container. The experimental boxes were placed in an incubator at 25 ± 1^oC, 75 ± 5% RH and photoperiod of 16L: 8D.

Daily consumption of each life stage was observed under a binocular stereo microscope by counting the number of *S. bispinosus* individuals left from the number of individuals supplied on the leaf disc, after 24 h. The predators were transferred to new leaf cups in the following day and the procedure was repeated until the larva reached adulthood. Each experiment was replicated eight times.

RESULTS AND DISCUSSION

Distribution

During the surveys, the predatory thrips *F. vespiformis* (Plate 1) was found preying on tea thrips *S. bispinosus* (Plate 2) in high ranges, the Nilgiris and Central Travancore regions of south India. This species was first reported in tea plantations of south India by Mahendran (2011). Later, Kaomud and Vikas (2013) and Varatharajan (2018) reported this species in Chhattisgarh, India and Cachar district, Assam respectively. In the present study, the adults and larvae of *F. vespiformis* were noticed on tea leaves on the upper canopy of tea bushes. The females were fast moving and very active over the tea bushes seeking and attacking the prey.

Prey population Vs predator density

More numbers of *F. vespiformis* was noticed in high ranges (Munnar), followed by Nilgiris (Coonoor) and Central Travancore regions (Vandiperiyar). Increase in predator population (*F. vespiformis*) coincided with the population increase of prey species (*S. bispinosus*) (Fig.1).

Life history

Life history of *F. vespiformis* studied providing *S. bispinosus* as prey revealed, egg, larva I, larva II, pupa I, pupa II and adult stages during the course of development. It laid eggs singly within the soft tissues of tea leaves and stems by using its ovipositor. The egg was kidney shaped and translucent in colour. *F. vespiformis* laid 43.27±1.29 eggs during the first five days of oviposition period; out of which 74.79±2.16 per cent hatched. However, the survival rate in immature was only 45.07±1.43 per cent (Table 1). The developmental duration of each life stage of *F. vespiformis* are shown in Table.2. Incubation of eggs took more than eight days to hatch, both larval instars (I and II) and pupa I lasted for two days each and pupa II took four days to become adult. The total developmental period from egg to adult stage was 18.45±0.27 days (Table 2). Both larva I and larva II preyed on tea thrips as actively as adults. Both larval stages were very similar to each other and possessed red hypodermal pigments. Second instar larva could be distinguished with red transverse bands on the head, prothorax and on the abdominal segments; but I instar larva was pigmented only on

Plate 1. *Franklinothrips vespiformis*

Plate 2. *Scirtothrips bispinosus*

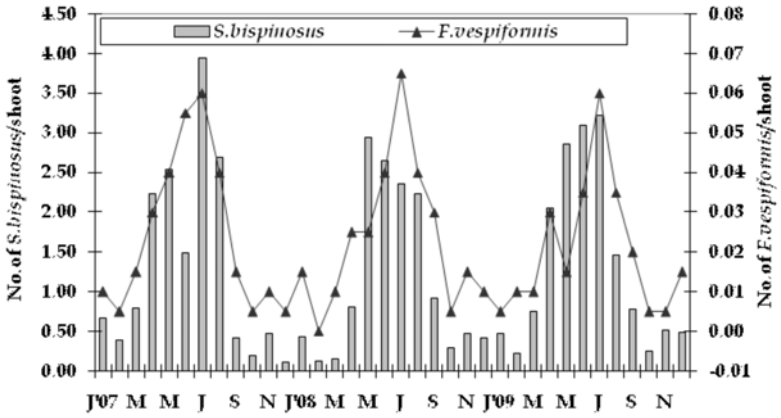

Fig. 1. Influence of prey density (*S. bispinosus*) on predator population (*F. vespiformis)* in tea ecosystem

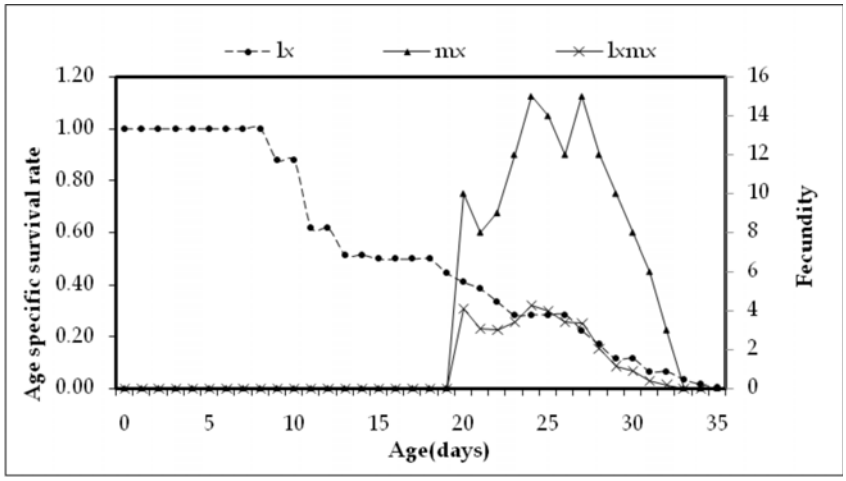

Fig. 2. Age specific survival rate (lx) age-specific fecundity rate (mx) and lxmx curves in *F.vespiformis.* lx=(eclosion of eggs) x (proportion of females alive at age x), mx= (proportion of females) x (age specific oviposition)

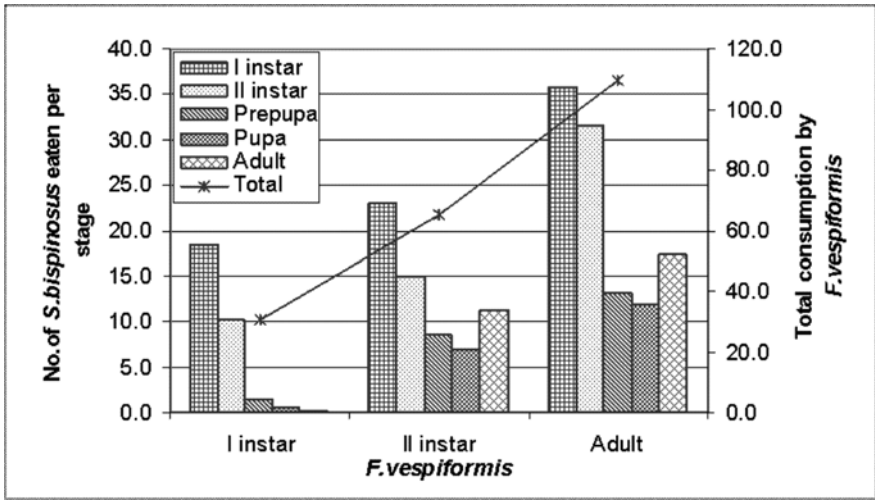

Fig. 3. Prey stage preference by *F. vespiformis* on different life stages of *S. bispinosus*

certain abdominal segments. Pupation took place on the leaf surface, the mature second instar larva during later stage spun cocoon and concealed inside. Initially the cocoon was transparent and the body of the pupa I was seen with its red hypodermal pigments. It again moulted inside the cocoon and reached the second pupal stage. This stage was little invisible since it was fully covered with silken material. In contrary to the above observations, Reijine (1920) and Stannard (1952) reported that members of this genus had just one pupal stage. However, Arakaki and Okajima (1998) and Sureshkumar and Ananthakrishnan (1987) reported two pupal stages for *Franklinothrips* sp. as reported in the present study. Cocoon spinning is a plesiotypic habit amongst terebrantian Thysanoptera, because it also occurs amongst species of Heterothripidae (Pinent *et al*., 2002).

Results of the present study also indicated a greater potential for population increase by this predator at 25°C when provided with *S. bispinosus* as feed. It laid 134.10±3.38 eggs/female in an oviposition period of 12.80±0.29 days. It had a total adult longevity of 16.80±0.25 days (Table 3). Parameters of population increase such as net reproductive rate (Ro), mean generation time (Tc), intrinsic rate of increase (rm), finite rate of increase (ë), weekly multiplication (Wm) and Doubling time (DT) at 25±2ºC, 75±5% RH are presented in Table 4. The sex ratio was completely female biased as the laboratory reared populations produced all females by thelytoky. Age specific survival rate (lx), age specific fecundity rate (mx) and lxmx curves in *F. vespiformis* are given in Fig. 2. These results are in accordance with Hoddle *et al.* (2000). They studied the life history of this species at different temperatures and reported that at 25°C, the demographic growth parameters were significantly greater than the same parameters calculated for *Franklinothrips* sp. at 20 and 30°C.

Predatory potential

The present study revealed that the adult stages of *F. vespiformis*, consumed more number of thrips than the larval instars (Table 5). However, per day consumption was more for second instar larva than the adult and first instar (Table 6). All the active

Table 1. No. of eggs laid during the first five days of the oviposition period, percentage hatchability in *F. vespiformis*

Parameter	N=15
No. of eggs laid/female[b]	43.27±1.29
No. of eggs hatched[b]	32.27±1.14
% hatchability[b]	74.79±2.16
% survival rate in immatures[b]	45.07±1.43

N - Number of females tested; *values shown are Mean±SE

Table 2. Developmental duration of different life stages of *F. vespiformis*

Life stages	Developmental duration in days (Mean±SE); N=20
Egg incubation	8.05±0.25
I instar	2.15±0.08
II instar	2.30±0.11
Pupa I	1.95±0.09
Pupa II	4.00±0.10
Total	18.45±0.27

N- Number of females tested

Table 3. Oviposition rates and various durations (in days) of female adults of *F. vespiformis* at three different temperatures under a 16L:8D photoperiod

Parameter	N=10
Total no. of eggs/female[b]	134.10±3.38
Pre-oviposition period[b]	1.10±0.10
Oviposition period[b]	12.80±0.29
Post oviposion period[b]	2.90±0.18
Total adult longevity[b]	16.80±0.25

N-Number of females tested; [b]Mean±SE

Table 4. Life Table - parameters of population increase (*F. vespiformis*) at 25 ± 2ºC, 75±5% RH

Net reproductive rate (Ro)=Ólxmx	74.769
Mean generation time (Tc)=ÓXlxmx/Ro	24.288
Intrinsic rate of natural increase (rm)	0.178
Finite rate of increase (ë)	1.194
Weekly multiplication (Wm)	3.468
Doubling time (DT)	3.902

Table 5. Feeding efficiency of predatory thrips, *F. vespiformis* on different life stages of *S. bispinosus*

Life stages of predator	Life stages of *S. bispinosus*				
	I instar	II instar	Prepupa	Pupa	Adult
I instar	41.8±2.13	24.3±1.66	13.9±1.41	10.5±0.87	4.3±0.25
II instar	87.4±2.94	65.1±2.23	59.3±1.47	55.4±1.19	50.8±1.68
Adult	174.1±5.51	132.5±4.20	102.5±2.64	94.5±2.48	88.6±3.06

values shown are mean±SE of 8 replicates

Table 6. Per day consumption by *F. vespiformis* on different life stages of *S. bispinosus*

Life stages of predator	Life stages of *S. bispinosus*				
	I instar	II instar	Prepupa	Pupa	Adult
I instar	10.4±0.53	6.1±0.41	3.5±0.35	2.6±0.22	1.1±0.06
II instar	21.8±0.73	16.3±0.56	14.8±0.37	13.8±0.30	12.7±0.42
Adult	19.1±0.69	14.6±0.63	11.6±0.38	11.1±0.33	9.9±0.40

Values shown are mean±SE of 8 replicates

life stages of *F. vespiformis* (larva I, larva II & adult) except the non-feeding pupa preferred mostly first instar larvae of *S.bispinosus* for feeding followed by the second instar (Fig. 3). Hoddle (2003) reported that *F. orizabensis* encountered and attacked more second instar larvae of *S. perseae* although attack rates on first and second instars were not significantly different. Though the first and second instars of *F. vespiformis* preferred first and second instars of *S. bispinosus* for feeding, they fed adults as well since they were efficient against adults. First instar larvae of *F. vespiformis*, did not prefer chasing the adults of *S. bispinosus* since they were little aggressive against this life stage. However, when there was no choice, first instar chased adults as well. Various members of the genus *Franklinothrips,* are considered to be useful biological control agents against pest thrips (Loomans and Heijboer, 1999; Loomans and Vierbergen, 1999).

As the present study showed the possibilities for the laboratory establishment of *F. vespiformis* as well as its predatory potential over *S. bispinosus*, this species can be effectively utilized as a prospective biocontrol agent in IPM program for the effective management of tea thrips.

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Performance of sorghum genotypes under zero tillage conditions in rice fallows with reference to stem borer, *Chilo partellus* (Swinhoe)

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ABSTRACT: A field experiment was carried out to screen the sorghum genotypes against stem borer in rice fallow under zero tillage condition. Based on mean stem tunnel length the genotypes were categorized as least susceptible (0-5 cm), moderately susceptible (5-10 cm), highly susceptible (>10 cm). The resistant check CSH 16 (C) found as least susceptible with 4.65 cm, whereas, NTJ-2 (C), NLCW-6 and N-14 were found to be highly susceptible as they recorded 10.45, 10.46 and 11.44 cm mean stem tunnel length respectively. The remaining genotypes found as moderately susceptible with 6.60 to 9.84 cm mean stem tunnel length. There is non-significant positive correlation between numbers of larvae with leaf damage, dead hearts stem tunneling, white ears and per cent chaffy grains, but it was negative with tiller damage.

KEY WORDS: Sorghum, stem borer, susceptible, stem tunnel length

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is the fifth major cereal crop after wheat, rice, maize and barley. It is an important crop of Asia, Africa, Australia, America and is cultivated as a staple crop in the semi-arid tropics (SAT). In India it is cultivated in an area of 6.18 m ha with 5.33 million tonnes production and productivity of 863 kg ha^{-1} (Agricultural Census, 2013). In general sorghum is cultivated during *kharif,* maghi (Late *kharif*) and *rabi* seasons in Andhra Pradesh in an area of 2,87,000 ha with production of 5,46,000 tonnes and productivity of 1904 kg ha^{-1} (Agricultural Statistics at a glance, 2012-2013) as against normal area 7,60,000 ha with production of 5,52,000 tonnes and productivity of 730 kg ha^{-1}. The reasons for low productivity under normal type of cultivation might be due to shifting of jowar area to cultivation of commercial crops, high humidity in coastal regions and ravage of pests and diseases in jowar cultivating areas.

Insect pest situations are dynamic in nature and changes with climate, farming practices, introduction of improved varieties have been known to result in pest outbreaks or changes in pest status (Duale and Nwanze, 1999). Sorghum is attacked by more than 150 insect species causing 32% crop loss (Borad and Mittal, 1983). Losses in sorghum due to insect pests differ in magnitude on a regional basis and have been estimated at US $ 1089 million in the SAT, US $ 250 million in USA and US $ 80 million in Australia (Anonymous, 1992). Among the insect pests,

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shoot fly, *Atherigona soccata* (Rondani) and stem borer, *Chilo partellus* (Swinhoe) are the major threatswith 75.6% and 24.3 to 36.3% yield losses respectively (Pawar *et al*., 1984).

Management of the pests is being done with the pesticides. But due to the adverse effects of pesticides it is imperative to seek for alternate integrated pest management methods like host plant resistance as it not only costless or require application skills in pest control techniques, but also enhance the effectiveness of natural enemies and reduce the need to use pesticides (Sharma, 1993). The effect of resistant genotypes on insect population is continuous and cumulative over time. Umakanth *et al*. (2004) reported 'SPV 1022', 'PKV809' and 'CO28' as promising sorghum cultivars in rice-fallows. Performance of sorghum genotypes under zero tillage conditions in rice fallows with reference to stem borer" was carried out during *rabi,* 2014 - 15 in the southern block of Agricultural College Farm, Bapatla.

MATERIALS AND METHODS

Investigation was carried out to screen the sorghum genotypes against stem borer in rice fallow under zero tillage condition. Thirty genotypes were procured from Directorate of Sorghum Research, Hyderabad and Regional Agricultural Research Station, Nandyal were used as source material for the screening study. Mahalakshmi 296, CSH 16, NTJ-1, NTJ-2, NTJ-3 and NTJ-4 were used as checks for this experiment. The experiment was laid out in randomized block design at Agricultural college Farm, Bapatla and the treatments were replicated twice. The crop was sown on 7-1-2015. The length of each line was 4 m and spacing between two lines of each genotype was 45 cm and intra row spacing adopted was 15 cm.

Observations were recorded on larval incidence. Number of larvae per plant were recorded by destructive sampling at vegetative, flowering, grain formation and harvesting stages. Dead hearts caused by *C. partellus* (Number of plants with dead hearts symptoms) and total number of plants were recorded from each plot based on which per cent dead hearts was calculated from 30 DAS to 60 DAS at weekly intervals). Stem tunneling at the time of harvesting, by destructive sampling (the main stem of plants infested with *C. partellus* were split open from the base to the apex, and the cumulative tunnel length and stem length measured in cm), the percentage tunneling was calculated.

Genotypes were categorized as given below, based on stem tunneling as per Rajasekhar and Srivastav (2013).

S. No.	Range of mean tunnel length (cm)	Attribute
1	0-5	Least susceptible
2	5-10	Moderately Susceptible
3	>10	Highly Susceptible

RESULTS AND DISCUSSION

Larval incidence during crop growth

Genotypes exhibited significant variation pertaining to larval incidence during their crop growth period. The data on number of larvae per plant recorded at vegetative stage ranged from 5.00 to 8.90. The highest number of larvae recorded in the genotype CSH 23 (8.90) followed by CSV 15 (8.50), SSV 84 (7.80), CSH 14 (7.80) and CSH 20MF (7.50) while the lowest number of larvae recorded in the genotype CSH 24MF, CSH 25, NTJ-4 (C) (5.00) followed by CSH 13 (5.10), N-14 (5.20) and BRJ-358 (5.60) compared to the resistant check CSH 16 (5.80) and Mahalaxmi 296 (6.80).

At flowering stage, the number of larvae per plant ranged from 4.50 to 11.40. Maximum number of larvae recorded in the genotype SSV 84 (11.40) followed by CSH 22SS (10.90), CSV 26 (9.90) and CSV 24SS (9.60). Minimum number of larvae recorded in the genotype N-14 (4.50) followed by NTJ-2 (C) (5.10), N-13 (5.90) and resistant check CSH 16 (C) (6.20) when compared to the popular check Mahalaxmi 296 (7.90) (Table 1).

At harvesting stage, the number of larvae per plant ranged from 3.20 to 7.60. The highest number of larvae recorded in NTJ-4 (C) (7.60) followed by NLCW-6 (6.70), NLCW-8 (6.60) and BRJ-358

Table 1. Reaction of sorghum genotypes against stem borer, *C. partellus* incidence during 2014-15

S. No	Genotype	No. of DH			No. of larvae per plant at -- stage		
		42 DAE	49 DAE	56 DAE	Vegetative	Flowering	Harvesting
1	CSV 24SS	0.01 (1.01)	0.01 (1.01)	0.02 (1.01)	5.90 (2.62)	9.60 (3.25)	5.00 (2.43)
2	CSH 22SS	0.00 (1.00)	0.00 (1.00)	0.01 (1.00)	7.10 (2.83)	10.90 (3.44)	4.10 (2.26)
3	CSV 23	0.00 (1.00)	0.00 (1.00)	0.02 (1.01)	7.00 (2.83)	8.60 (3.10)	6.00 (2.64)
4	CSH 20MF	0.00 (1.00)	0.00 (1.00)	0.01 (1.00)	7.50 (2.91)	7.60 (2.93)	4.40 (2.32)
5	CSH 24MF	0.00 (1.00)	0.01 (1.01)	0.05 (1.02)	5.00 (2.45)	6.70 (2.77)	5.60 (2.56)
6	CSV 17	0.00 (1.00)	0.00 (1.00)	0.01 (1.00)	7.40 (2.89)	8.30 (3.05)	5.30 (2.49)
7	SSV 84	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	7.80 (2.96)	11.40 (3.39)	3.70 (2.17)
8	CSV 216R	0.01 (1.00)	0.02 (1.01)	0.04 (1.02)	6.50 (2.74)	8.80 (3.11)	3.90 (2.21)
9	CSV 15	0.00 (1.00)	0.01 (1.00)	0.02 (1.01)	8.50 (3.07)	9.20 (3.18)	3.20 (2.03)
10	CSH 14	0.01 (1.01)	0.00(1.00)	0.03 (1.02)	7.80 (2.97)	6.30 (2.70)	3.80 (2.16)
11	CSV 22	0.02 (1.01)	0.02 (1.01)	0.03 (1.02)	7.20 (2.86)	8.90 (3.14)	3.90 (2.21)
12	CSV 26	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	6.80 (2.79)	9.90 (3.29)	3.90 (2.21)
13	CSH 23	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	8.90 (3.14)	7.30 (2.88)	3.40 (2.10)
14	CSV 29R	0.00 (1.00)	0.00 (1.00)	0.01 (1.01)	6.50 (2.72)	9.00 (3.16)	3.50 (2.12)
15	CSH 30	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	6.70 (2.77)	6.80 (2.79)	3.40 (2.10)
16	CSV 14R	0.00 (1.00)	0.01 (1.01)	0.01 (1.01)	7.20 (2.86)	6.40 (2.72)	3.90 (2.21)
17	CSH 13	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	5.10 (2.46)	9.30 (3.19)	4.50 (2.34)
18	CSH 25	0.01 (1.01)	0.01(1.00)	0.01 (1.00)	5.00 (2.45)	6.30 (2.70)	5.30 (2.50)
19	N-13	0.02 (1.01)	0.04 (1.02)	0.04 (1.02)	6.90 (2.81)	5.90 (2.63)	5.70 (2.59)
20	N-14	0.01 (1.01)	0.01 (1.01)	0.01 (1.01)	5.20 (2.49)	4.50 (2.34)	6.00 (2.65)
21	BRJ-358	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	5.60 (2.57)	8.70 (3.11)	6.50 (2.74)
22	NLCW-6	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	6.60 (2.75)	8.90 (3.14)	6.70 (2.77)
23	NLCW-8	0.00 (1.00)	0.00 (1.00)	0.04 (1.02)	6.20 (2.66)	7.60 (2.93)	6.60 (2.75)
24	NLCW-12	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	7.30 (2.88)	8.30 (3.04)	6.30 (2.70)
25	Mahalaxmi 296 (C)	0.01 (1.01)	0.01 (1.01)	0.01 (1.01)	6.80 (2.78)	7.90 (2.98)	4.80 (2.41)
26	CSH 16 (C)	0.00 (1.00)	0.02 (1.01)	0.03 (1.02)	5.80 (2.61)	6.20 (2.68)	4.00 (2.24)
27	NTJ-1 (C)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	7.40 (2.88)	7.50 (2.88)	5.20 (2.49)
28	NTJ-2 (C)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	6.70 (2.76)	5.10 (2.47)	5.60 (2.54)
29	NTJ-3 (C)	0.00 (1.00)	0.00 (1.00)	0.01 (1.00)	6.10 (2.66)	7.30 (2.86)	4.40 (2.32)
30	NTJ-4 (C)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	5.00 (2.45)	6.90 (2.80)	7.60 (2.93)
	SEm±	0.09	0.10	0.09	0.18	0.23	0.16
	CD (0.05%)	0.26*	0.29*	0.27*	0.53*	0.65*	0.47*
	CV%	12.90	14.20	13.20	9.42	10.8	9.48

Values in the parenthesis are square root transformed values. * = Significant

DH = dead jearts' (c) = Check

Table 2. Per cent dead hearts infestation in different sorghum genotypes cultivated under zero tillage in rice fallows during 2014-15

S.No	Genotype	42 DAE	49 DAE	56 DAE
1	CSV 24SS	1.14 (4.34)	1.14 (4.34)	2.27 (6.16)
2	CSH 22SS	0.00 (0.00)	0.00 (0.00)	1.00 (4.07)
3	CSV 23	0.00 (0.00)	0.00 (0.00)	1.96 (5.71)
4	CSH 20MF	0.00 (0.00)	0.00 (0.00)	1.00 (4.07)
5	CSH 24MF	0.00 (0.00)	1.11(4.29)	4.92 (12.81)
6	CSV 17	0.00 (0.00)	0.00 (0.00)	0.98 (4.03)
7	SSV 84	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
8	CSV 216R	0.96 (3.99)	1.92 (5.66)	4.24 (11.69)
9	CSV 15	0.00 (0.00)	0.96 (3.99)	1.92 (5.66)
10	CSH 14	0.96 (3.99)	0.00 (0.00)	3.46 (10.45)
11	CSV 22	2.22 (8.56)	2.44 (6.38)	3.44(10.45)
12	CSV 26	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
13	CSH 23	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
14	CSV 29R	0.00 (0.00)	0.00 (0.00)	1.02 (4.11)
15	CSH 30	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
16	CSV 14R	0.00 (0.00)	1.28 (4.61)	1.28 (4.61)
17	CSH 13	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
18	CSH 25	1.00 (4.07)	1.00 (4.07)	1.00 (4.07)
19	Mahalaxmi 296 (C)	1.02 (4.11)	1.02 (4.11)	1.02 (4.11)
20	CSH 16 (C)	0.00 (0.00)	1.61 (5.18)	3.23 (7.36)
21	N-13	2.18 (8.50)	4.37 (12.06)	4.37 (12.06)
22	N-14	1.02 (4.11)	1.02 (4.11)	1.02 (4.11)
23	BRJ-358	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
24	NLCW-6	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
25	NLCW-8	0.00 (0.00)	0.00 (0.00)	3.55 (10.73)
26	NLCW-12	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
27	NTJ-1 (C)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
28	NTJ-2 (C)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
29	NTJ-3 (C)	0.00 (0.00)	0.00 (0.00)	0.96 (3.99)
30	NTJ-4 (C)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SEm±	0.10	0.18	0.42
	CD (0.05%)	0.29*	0.53*	1.23*
	C V%	10.30	12.30	13.80

Values in the parenthesis are arcsine transformed values. (c) = Check

Table 3. Reaction of sorghum genotypes against *Chilo partellus* infestation at different crop growth stages

S.No	Genotype	Stem tunneling percentage	Mean stem tunnel length in cm	Attribute
1	CSV 24SS	5.56 (13.64)	8.78	MS
2	CSH 22SS	4.78 (12.64)	9.45	MS
3	CSV 23	5.71 (13.83)	9.13	MS
4	CSH 20MF	5.12 (13.08)	8.98	MS
5	CSH 24MF	3.53 (10.84)	6.10	MS
6	CSV 17	8.53 (16.99)	8.37	MS
7	SSV 84	5.81 (13.95)	9.35	MS
8	CSV 216R	4.39 (12.10)	8.87	MS
9	CSV 15	5.74 (13.87)	8.07	MS
10	CSH 14	5.99 (14.17)	8.34	MS
11	CSV 22	4.39 (12.11)	8.57	MS
12	CSV 26	3.38 (10.60)	6.60	MS
13	CSH 23	5.16 (13.14)	7.83	MS
14	CSV 29R	4.76 (12.60)	9.19	MS
15	CSH 30	5.83 (13.98)	8.65	MS
16	CSV 14R	4.50 (12.25)	8.60	MS
17	CSH 13	4.42 (12.14)	9.14	MS
18	CSH 25	5.55 (13.63)	9.48	MS
19	Mahalaxmi 296 (C)	5.01 (12.94)	9.84	MS
20	CSH 16 (C)	6.70 (15.01)	4.65	LS
21	N-13	5.46 (13.51)	8.98	MS
22	N-14	9.37 (17.83)	11.44	HS
23	BRJ-358	7.44 (15.84)	9.50	MS
24	NLCW-6	7.80 (16.22)	10.46	HS
25	NLCW-8	6.78 (15.10)	9.60	MS
26	NLCW-12	3.51 (10.80)	7.80	MS
27	NTJ-1 (C)	6.60 (14.89)	8.58	MS
28	NTJ-2 (C)	5.76 (13.90)	10.45	HS
29	NTJ-3 (C)	4.24 (11.88)	9.52	MS
30	NTJ-4 (C)	4.95 (12.86)	9.32	MS
	SEm±	0.82	0.79	
	CD (0.05%)	2.38*	2.30*	
	CV%	17.0	12.8	

Values in the parenthesis are arcsine transformed values

. * = Significant. MS= Moderately susceptible, HS= Highly susceptible and LS= Least susceptible.

(6.50) while the lowest number of larvae per plant recorded in the genotype CSV 15 (3.20) followed by CSH 23, CSH 30 (3.40), CSV 29R (3.50) and SSV 84 (3.70) compared to the resistant check CSH 16 (4.0), NTJ-3(4.40) and popular check Mahalaxmi 296 (4.80). Mohan *et al.* (1990) reported that the highest seasonal incidence of *C. partellus* on variety HC-136 and JS-20 during *rabi*-summer and *kharif* and larval and pupal populations found to be high during *kharif* season crop than in *rabi*-summer. Adverse effect of resistant genotypes on insect development resulting in low larval mass due to nutritional abnormalities and/or because of poor food utilization by the larvae of resistant varieties (Jotwani *et al*., 1978). Painter (1951) suggested that with rare exceptions, the feeding of insects during the developmental stages on resistant varieties results in individuals that are smaller and have less weight. The sorghum varieties appear to possess some antibiotic factors which exist either in the leaves or in the stem or in both and influence the larval duration adversely (Lal and Sukhani, 1982; Singh and Rana, 1984).

Dead hearts caused by stem borer

The results revealed that at 42 DAE, the number of dead hearts and percent dead hearts ranged from 0.00 to 0.02 and 0.00 to 2.22% respectively. The highest number of dead hearts and percent dead hearts observed in the genotype CSV 22 (0.02 and 2.22), N-13 (0.02 and 2.18) followed by CSV 216R (0.01 and 1.14), CSH 25 (0.01 and 1.00), N-14 and popular check Mahalaxmi 296, resistant check CSH 16 (C) (0.01 and 1.02) and CSV 24SS (0.01 and 1.14). There is no infestation was recorded in the remaining all the genotypes (Table 2).

At 49 DAE, the number of dead hearts and percent dead hearts ranged from 0.00 to 0.04 and 0.00 to 2.44% respectively. The highest number of dead hearts and percent dead hearts observed in the genotype N-13 (0.04 and 4.37) followed by CSV 22 (0.02 and 2.44), CSV 216R, popular check Mahalaxmi 296 (0.02 and 1.61), CSV 216R (0.02 and 0.96) and N-14 and CSH 25 (0.01 and 1.00). The remaining all the genotypes were not recorded the infestation. Similar trend reaction was noticed at 56 DAE. The number of dead hearts and percent dead hearts ranged from (0.00 to 0.05 and 0.00 to 4.92). Very less number of dead hearts were recorded in the tested genotypes.

The present investigation revealed that the percent dead hearts range was very low. These findings are in conformity with the findings of Hussian *et al* (2014) who recorded lowest stem borer dead hearts in the genotype CSH 23 (4.87) and Vyas *et al.* (2014) recorded 2.39% in CSV 21F and 3.58% in CSH 20MF in *kharif* season. The third instar larvae migrate to the base of the plant, bore into the shoot and damage the growing point resulting in the formation of dead heart. The reason might be the influence of weather as the crop is cultivating during off-season and physico-chemical properties responsive for the development of stem borer.

Stem tunneling damage caused by *C. partellus*

After causing damage to the gowing point of the plant, *C. partellus* continue to feed inside the stem throughout the crop growth and cause tunnels inside the stem. The data recorded on stem tunneling revealed that mean stem tunnel length ranged from 6.60 to 10.46 cm with 3.38% to 7.80% tunneling (Table 3). Marulasiddesha *et al.* (2007) recorded 32.57% stem tunneling in the genotype SSV 84 and 49.15 % in CSH 14.

Based on mean stem tunnel length the genotypes were categorized as least susceptible (0-5 cm), moderately susceptible (5-10 cm), highly susceptible (>10 cm). The genotype resistant check CSH 16 (C) found as least susceptible with 4.65 cm, whereas, NTJ-2 (C), NLCW-6 and N-14 were found to be highly susceptible as they recorded with mean stem tunnel length of 10.45, 10.46 and 11.44 cm respectively. The remaining genotypes found as moderately susceptible with 6.60 to 9.84 cm mean stem tunnel length.

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Study on varietal preferences and seasonal incidence of parasitoids of rice pests

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ABSTRACT: The egg masses of yellow stem borer, larvae of leaf folder and rice horned caterpillar and eggs of ear head bug were collected randomly at fortnightly interval from four different varieties *viz*., CO 43, CO 50, CO 51 and CR 1009 from the rice field. The data was pooled and per cent parasitization was calculated to find out the varietal preference and seasonal variations of parasitoids. Among the four different varieties tested for the preference of parasitoids, per cent parasitization of stem borer egg mass was found to be more (26.59) in CO 50. The per cent parasitization of leaf folder larvae and rice horned caterpillar was found to be maximum in CO 51(40.29) and CO 43(33.21), respectively. In case of ear head bugs, the egg parasitization was maximum (27.70) in CO 50. The mean egg mass parasitization of stem borer was highest (71.88) in first fortnight of December. The larval parasitization of leaf folder and rice horned caterpillar were found to be maximum during the second fortnight of December (64.3) and the first fortnight of January (71.88), respectively. The parasitism rate of ear head bug eggs was maximum (62.95) during the second fortnight of December. Interestingly, phoresy exhibited by *Sceliocerdo* sp. an egg parasitoid of *Neorthacris* sp. was also recorded.

KEY WORDS: Rice, varieties, preferences, parasitoids, seasonal variations

INTRODUCTION

In India, rice is not just a food stuff, but a culture. Tamil Nadu, one of the leading rice growing states in India, has been cultivating rice from time immemorial as this state is endowed with all favourable climatic conditions suitable for growing rice. Insect pests are reported as the major threat to rice production and the overall losses due to insect pest damage in rice is estimated as 25 per cent (Pathak and Dhaliwal, 1981; Dale, 1994). Farmers generally rely on insecticides to combat pest problems. Indiscriminate use of insecticides resulted in the loss of biodiversity of beneficial organisms like parasitic hymenopterans (Dudley *et al.,* 2005). Reducing the mortality of parasitic hymenopterans caused by insecticides is essential for greater sustainability in rice pest management (Heong and Hardy, 2009; Gurr *et al*., 2011). If the use of insecticides is to be reduced through Integrated Pest Management, then the consequent reduction in pest control has to be augmented in some way and no

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doubt, parasitic hymenopterans are the best alternatives to pesticides. They show greater stability to ecosystem than any group of natural enemies of insect pests because they are capable of living and interacting at lower host population level. To aid this means of pest control, it is essential that the diversity and host range, varietal preferences and seasonal incidence of parasitoids needs to be studied first (Dey *et al.,* 1999). Despite their importance, our understanding of their biology and diversity is clearly wanting. Therefore, more emphasis should be given for the identification, conservation and use of parasitic Hymenoptera in insect pest management programmes. This will render high economic returns to the farmers besides sustainable ecofriendly pest management.

Wagge (1991) has pointed out that it is fundamentally important to conserve a large reservoir of parasitic hymenopteran diversity, regardless of what we know about the taxonomy or biology of that reservoir, because we can not predict which species might become pest in the future. We will not make any real progress in our understanding of parasitic Hymenoptera without additional commitment to research. Any additional knowledge in seasonal incidence, biology, host range is of potential practical value. In these context, the present study was undertaken.

MATERIALS AND METHODS

The egg masses of yellow stem bores, larvae of leaf folder and rice horned caterpillar and eggs of ear head bug were collected randomly at fortnightly interval from four different varieties viz., CO 43, CO 50, CO 51 and CR 1009 from the rice field of Paddy Breeding Station, Tamil Nadu Agricultural University, Coimbatore during December 2016 to May 2017. The collected host insects were placed in suitable emergence cages/ vials and Petri dishes are monitored for the emergence of parasitoids. Emerged were preserved in 70% ethyl alcohol. The dried specimens were mounted on pointed triangular cards and studied under a Stemi (Zeiss) 2000-C and Photographed under Leica M 205-A stereo zoom microscope and identified through conventional taxonomic techniques by following standard keys. In addition, help was also taken from already identified collection of parasitoids at Parasitoid Taxonomy Lab, Annamalai University, Chidambaram. Identified collections are deposited at Insect Biosystematics lab, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore.

The data was pooled and per cent parasitization was calculated to find out the varietal preference and seasonal variations of parasitoids. The statistical test ANOVA was also used to check whether there was any significance in varietal preferences of parasitoids and seasonal variations among them. The data on per cent were transformed into arc sine before statistical analysis. The per cent parasitization from four different varieties and per cent parastization among six months were analyzed by adopting Randomized block design (RBD) to find least significant difference (LSD). Critical difference (CD) values were calculated at five per cent probability level. All these statistical analyses were done using Microsoft Excel 2016 version and Agres software version 3.01.

RESULTS

In the present study, major parasitoids of egg masses of rice stem borer, larvae of rice leaf folder, larvae of rice horned caterpillar and egg masses of rice ear head bug were identified *viz*., *Tetrastichus schoenobii* Ferriere, *Goniozus indicus* (Ashmead), *Pediobius inexpectatus* Kerrich, and *Gryon orestes* (Dodd) respectively (Fig. 1-4). Among the four different varieties tested, per cent parasitization of stem borer egg mass was found to be more in CO 50 (26.59) followed by CR 1009 (26.25). The per cent parasitization of leaf folder larvae was found to be maximum in CO 51 (40.29) followed by CO 50 (38.12). CO 43 and CR 1009 were found to be almost on par with each other. The parasitization efficiency in rice horned caterpillar was more in CO 43 (33.21%) followed by CR 1009 (30.29%). In case of ear head bugs, the egg parasitization was maximum in CO 50 (27.70%) followed by CO 51 (24.31%) (Table 1). The per cent parasitization by rice parasitoids was comparatively higher in case of CO 50 and CO 51 for stem borer, leaf folder and ear head bug, whereas it was less in rice horned caterpillar;

although no statistical significance was observed amongst any of the varieties and pest incidence.

There was no statistical significance difference in the per cent parasitizaton of parasitoids (Table 2). However egg mass parasitization of stem borer was the highest in first fortnight of December (71.88%) followed by December second fortnight (44.74%) and from January, it started declining and reached a peak at first fortnight of March (31.59%) and reached nil during May. The larval parasitization of leaf folder was found to be maximum during the second fortnight of December (64.3%) and was comparatively nil during second week of January. The parasitization of rice horned caterpillar reached its peak during the first fortnight of January (71.88%) and the least during second fortnight of April (6.25%). Egg parasitization of ear head bug was observed from December to May except second fortnight of January and first fortnight of April. The parasitism rate of ear head bug eggs was maximum in second fortnight of December. It started declining from fortnight of March and found nil parasitism during first fortnight of April (Fig. 5). So it is clear

Fig. 1. *Tetrastichus schoenobii* Ferriere parasitizing egg masses of rice stem borer

Fig. 2. *Pediobius inexpectatus* Kerrich parasitizing the larva of rice horned caterpillar

rice

Fig. 3. *Gryon orestes* (Dodd) emerging from the eggs of rice ear head bug

Fig. 4. *Goniozus indicus* (Ashmead) feeding on rice leaf folder larva

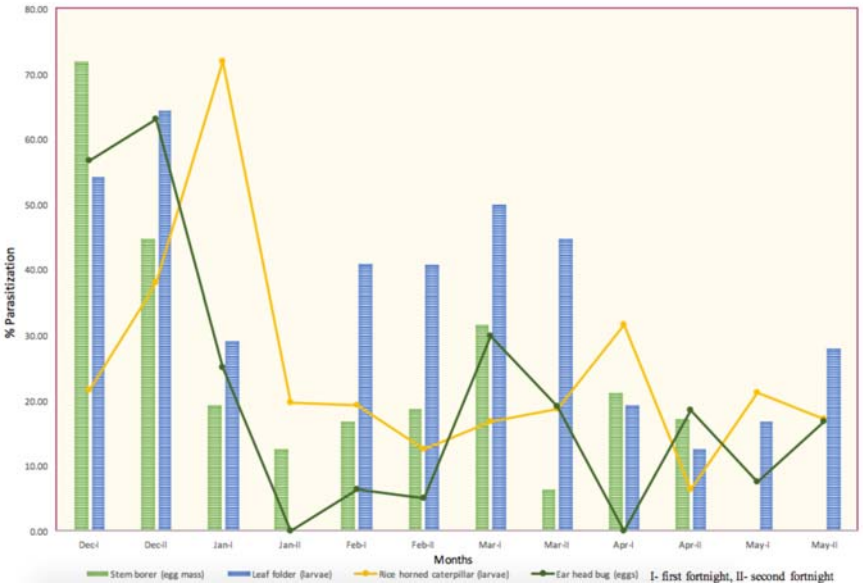

Fig. 5. Seasonal variations in per cent parasitization of different parasitoids

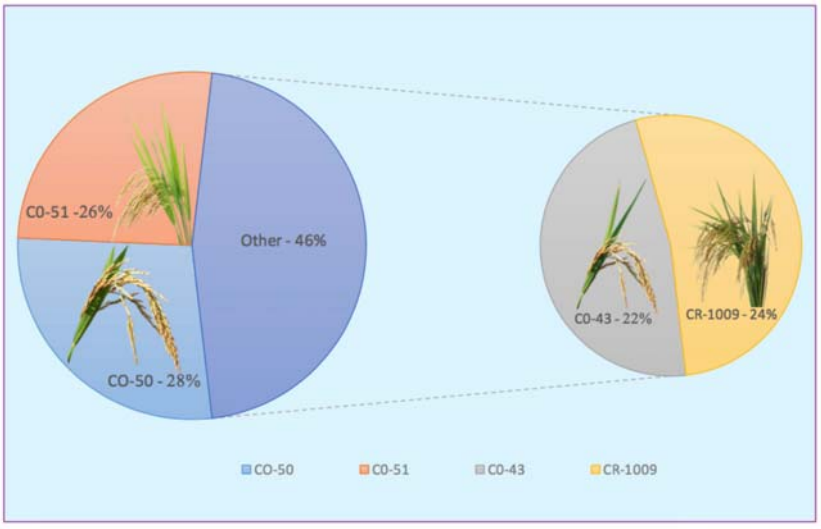

Fig. 6 Varietal preference of parasitoids from rice ecosystem (% parasitization by different parasitoids)

Fig 7. Phoresy exhibited by *Sceliocerdo* sp. on *Neorthacris* sp

that among the six months, i.e. from December to May, parasitoid activity for all the pests was maximum between December and January.

DISCUSSION

Varietal preferences of parasitoids towards the host insects in different varieties of plant species have been reported (Loughrin *et al.,* 1995; Turlings *et al.,* 1998; Krips *et al.,* 2001; Degen *et al.,* 2004).

Table 1. Varietal preference of different parasitoids on rice pests

Variety	Per cent parasitization on			
	Stem borer (egg mass)	Leaf folder (larvae)	Rice horned caterpillar (larvae)	Ear head bug (eggs)
CO 43	10.32 ± 7.64(9.62)	27.84 ± 9.85(24.74)	33.21 ± 10.04(30.24)	16.73 ± 9.35(14.65)
CO 50	26.59 ± 9.86(22.76)	38.12 ± 12.29(33.21)	17.92 ± 10.07(16.37)	27.70 ± 11.81(25.64)
CO 51	23.47 ± 9.75(22.03)	40.29 ± 11.46(35.64)	16.73 ± 9.35(14.65)	24.31 ± 9.45(23.67)
CR 1009	26.25 ± 11.98(23.72)	27.08 ± 12.10(24.20)	30.29 ± 9.65(26.16)	13.75 ± 7.52(12.69)
S.E.D	11.07	13.85	11.43	10.45
C.D (p=0.05)	22.53 NS	28.18 NS	23.27 NS	21.27 NS

Figures in parentheses are Arc sine transformed values; NS = nonsignificant.

Table 2. Seasonal incidence of parasitoids in rice ecosystem (2016 – 2017)

Months	Per cent parasitization			
	Stem borer (egg mass)	Leaf folder (larvae)	Rice horned caterpillar (larvae)	Ear head bug (eggs)
December- I	71.88 ±24.1(62.12)	54.2 ± 20.8(47.44)	21.57 ± 12.46(20.94)	56.73 ± 21.49(49.07)
December- II	44.74 ± 26.2(38.38)	64.3 ± 12.0(57.07)	37.98 ± 21 .93(30.74)	62.95 ± 19.39(56.42)
January- I	19.23 ± 19.2(15.94)	29.2 ± 23.9(28.73)	71.88 ± 24.14(62.12)	25.00 ± 25.00(22.91)
January- II	12.50 ±12.5(11.87)	0.0 ± 0.0(0.83)	19.74 ± 19.74(16.29)	0.00 ± 0.00(0.83)
February- I	16.67 ± 16.7(14.30)	40.8 ± 15.8(36.06)	19.23 ± 19.23(15.94)	6.25 ± 6.25(8.12)
February- II	18.75 ± 18.8(15.62)	40.6 ± 23.6(32.74)	12.50 ± 12.50(11.87)	5.00 ± 5.00(7.26)
March- I	31.59 ± 10.9(30.54)	50.0 ± 28.9(45.00)	16.67 ± 16.67(14.30)	29.86 ± 18.33(25.87)
March- II	6.25 ± 6.3(8.12)	44.7 ± 26.2(38.38)	18.75 ± 18.75(15.62)	19.09 ± 11.05(19.49)
April- I	21.25 ± 12.3(20.75)	19.2 ± 19.2(15.94)	31.59 ± 10.92(30.54)	0.00 ± 0.00(0.83)
April- II	17.05 ± 17.0(14.54)	12.5 ± 12.5(11.87)	6.25 ± 6.25(8.12)	18.42 ± 18.42(15.40)
May- I	0.00 ± 0.0(0.83)	16.7 ± 6.7(14.30)	21.25 ± 12.31(20.75)	7.50 ± 7.50(8.92)
May- II	0.00 ± 0.0(0.83)	27.8 ± 17.9(24.69)	17.05 ± 17.05(14.54)	16.67 ± 16.67(14.30)
S.E.D	19.18	23.99	19.81	18.11
C.D . (p=0.05)	39.03 NS	48.82 NS	40.31 NS	36.84 NS

Figures in parentheses are Arc sine transformed values; NS = nonsignificant

Many parasitoids are reported to have keen ability to learn and respond to specific odor by associating the odor emitted from host plant or host insect or host insect feces (Lewis and Tumlinson, 1988; Vet and Groenewold, 1990; Turlings *et al.,* 1993). Chemical and morphological plant attributes can directly influence the survival, fencundity, and foraging success of natural enemies on hosts. Morphological traits, such as prominent leaf veins or moderate pubescence, are reported to provide sheltered habitats for small natural enemies and promote their abundance (Drowning and Moillet, 1967; Walter and O'Dowd, 1992; Hance and Boivin, 1993; Karban *et al.,* 1995; Corbett and Rosenheim, 1996; Elkassabany *et al.,* 1996; Walter, 1996). This fact is in support of our findings (Fig. 6) which showed that the cumulative parasitization per cent of all parasitoids was comparatively higher in CO-51 and CO-50, the varieties with moderate pubescence. Such structures can supply water and shelter for parasitoids and constitute a key factor in the maintenance of their populations. A waxy surface and shape of a leaf are other morphological traits that can influence the host selection by parasitoids (Futuyma and Keese, 1992).

Only few studies have demonstrated the importance of different varieties of plants- induced odor emissions outside the laboratory (Scutareanu *et al.,* 1997; De Moraes *et al.,* 1998; Thaler, 1999; Kessler and Baldwin, 2001; Lou *et al.,* 2005; Rasmann *et al.,* 2005). One of those studies (Rasmann *et al.,* 2005) also shows that the effectiveness of the natural enemies in the field can be enhanced by planting crop varieties that emit the appropriate volatile signal from their leaves. The results reported here in the present study represent an example of varietal preferences of different parasitoids in the rice field. However, in the present study neither did the parasitoids show any significant preference for a variety nor was there any significant difference in the seasonal incidence of the parasitoids. Possibly encouraging results could have been obtained if the trials are repeated with more varieties and for more seasons. Therefore, more researches like this should be encouraged with more varieties and extended period of time to bridge the gap of the present study. Special emphasis should now be placed on breeding crop plants with natural enemy enhancing traits, thereby enhancing the parasitic potential of parasitoids in rice ecosystems.

From the present study, it is clear that among the six months, i.e. from December to May, parasitoid activity for all the pests was maximum between December and January. This is in accordance with the study conducted in Tamil Nadu Agricultural University by **Chandramohan and Chelliah (1990)** which revealed that, the peak activity of *Tetrastichus schoenobii* was seen between October to January months. They have also reported that, among the larval parasitoids, *Apanteles* sp. registered maximum parasitism during January-February months in Paddy Breeding Station, Coimbatore, the place where the present study was also conducted. The reason for the reduction of parasitization may be due to the increase in temperature in succeeding months. Increase in temperature during summer months might have impaired the parasitic activity resulting in negative association with maximum temperature. Parasitization by *T. schoenobii* in Andhra Pradesh, India was 30.6 per cent during kharif and 23.7 per cent during rabi season. But the rate of parasitization in laboratory condition, extended up to 48 per cent **(Gupta *et al.,* 1985**). *Tetrastichus* sp. was the main egg parasitoid during kharif season in Warangal, Haryana **(Rao *et al.,* 1983)**. Parasitism by *Telenomus* during October and November was 26.84 per cent (Rao et al., 1976). *Telenomus dignoides* was found more during September, at Kapurthala, Punjab, whereas maximum activity of *T. dignoides* was noticed at Cuttack, Orrisa, during December. Both the incidence of egg mass and the extent of parasitism were more during rabi season **(Sukhija *et al.,* 1991)**. These results are in accordance with our findings. Interestingly, phoresy exhibited by *Sceliocerdo* sp., an egg parasitoid of short horned wing less grasshopper pest of paddy, *Neorthacris* sp. on a weed from the bunds of rice fields (Fig. 7). This phoretic genera is the first report in rice ecosystem. Rajmohana (2014) have specifically mentioned that it is yet to be reported from rice ecosystem.

The majority of research related to arthropods in tropical rice has been directed towards the small number of pests and natural enemies species without examining the abiotic linkages to the rest of the system. Modern pest control tactics are mainly dependent on the exploitation of the linkages between biotic and abiotic factors to maximize pest population suppression. This can be possible only by understating the underpinnings of seasonal variations in parasitod activity.

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Study on adult emergence, female calling and mating behaviour in *Maruca vitrata* F. (Lepidoptera: Crambidae) in Kerala, India

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ABSTRACT: Behavioural studies on the legume spotted pod borer, *Maruca vitrata* was done at 27±2°C, 65-70% RH and photoperiod of 12L: 12D. Adult emergence occurred throughout the day. Emergence of moths during scotophase (6 pm - 5 am) was 70%, which constitutes 63% of males and 76% of females. During photophase, (6 am - 5 pm) emergence was 30%, which constitutes 36% for males, and 24% for females. Highest emergence peak for male was observed at 4 pm (photophase) and for females, at 10 pm (scotophase). Calling behaviour of *M.vitrata* females observed from one to eight days. Female started calling from 2nd hour of scotophase (7 pm) and terminated at 3 am (scotophase). The mean percentage of calling was maximum at 6th hour of scotophase in 3-day old moth with 44%. None of the females called during first hours of scotophase. Mating of *M. vitrata* observed throughout scotophase up to 8 days and highest mating occurred in 3-day-old moths with 26%.

KEY WORDS: Adult emergence, female calling, mating behavior, *Maruca vitrata*

INTRODUCTION

The legume spotted pod borer *Maruca vitrata* (Fabricius, 1787) is an important pest because of its extensive distribution, wide host range, and destructiveness (Taylor, 1967). It is a specific key pest of cowpea (Jackai, 1995). The Indo-Malaysian region is considered as the most probable center of origin for the genus *Maruca*, including *M. vitrata,* which is found throughout the tropics (CABI, 2002). It shows broad range of dispersal throughout Africa, South America, southern states of Australia, and Asia (Singh and Emden, 1979). The larvae are voracious feeders of flower buds, flowers, and young pods (Jackai and Singh, 1983). Thus, infestation can occur at all stages of crop from seedling to pod forming stage. The infested pod with bored holes plugged with excreta render the pods unmarketable and leads to considerable yield loss up to 20-80%. In the order Lepidoptera, adult emergence and sexual behaviour occur in a specific period of the day and season. In females, sexual behaviour consists of production and release of sex

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pheromones through calling behaviour, leading to attraction of potential mates, and the receptivity to males that attempt mating (Kingan *et al*., 1993). The knowledge of adult emergence, female calling, and mating behaviour helps in implementation of semio-chemical based pest management methods. The present study is an attempt to understand adult emergence, female calling, and mating behaviour of *M. vitrata.*

MATERIALS AND METHODS

Rearing of insects

Larvae of *M. vitrata* were collected from infested flowers and young pods of cowpea. Larvae were maintained in rearing room at the temperature of 27±2°C and relative humidity of 65-70%, photoperiod of 12L: 12D in the department of Entomology, College of Agriculture, Padannakkad. Larvae were reared individually to prevent cannibalism by keeping them in transparent plastic containers of 7 cm diameter and 12 cm height size with absorptive paper. First and second instar larvae were provided with flowers and flower buds of cowpea as food. Later instars were fed with pods, flower and flower buds. After pupation, pupae were separated based on genital characters and kept in separate boxes.

Adult emergence pattern

Well developed silken cocooned late pupa (N=160) were selected and kept in separate containers individually on tissue paper (Ke *et al*., 1985). The pattern of emergence was recorded at hourly records from 0-24 hours. The number of emerged moths were recorded per unit time for each sex (12L: 12D). Observations were taken during scotophase with help of LED lamp of 2 to 3 watts, which was covered with red cellophane. Emerged moths were separated in to males and females based on abdominal features (Fig.1 A, B). Mean percentage of moths emerged per hour was recorded.

Female calling behaviour

Twenty female moths of one day old (0-24h) were confined to a transparent cylindrical plastic container of 12.5 cm diameter; 24 cm height size individually and provided with ventilation. Moths were provided with 10% honey soaked cotton ball as food. The calling of the female moths of 1-8 day old were observed throughout scotophase (lights off at 18:00 and on at 06:00 h) within every 15 minutes interval. Females exhibiting extrusion and protrusion of pheromone gland scored as calling females. Light was provided using LED 3w lamp with red cellophane during scotophase. ANOVA was used to analyze the results.

Mating behaviour

Soon after the emergence, 15-30 active pairs of one day old moths were selected and placed individually in clear ventilated cylindrical plastic containers of 12.5 cm diameter; 24 cm height size and left to mate. Observations were initiated instantly after pairing at every 15 min interval up to 8 days. Moist filter paper was provided to maintain humidity and honey soaked cotton balls in the containers. Number of pairs initiated to mate were observed for every 15 min and calculated for each hour. In addition, onset time of mating and duration of mating for each pair recorded. The courtship behavior such as male advancement towards female, exposing its hair pencils and mating position were observed. Virgin males with mated females and mated males with virgin females were observed separately to know the possibility of multiple mating.

RESULTS

In adult emergence studies both the sexes were observed throughout the day for emergence, it was observed that 30% of moths emerged during photophase (6am-5pm) and 69.68% of moths emerged during scotophase (6 pm – 5 am). Moths emerged during photophase had a gender distribution of 36.25% males and 23.75% females whereas during scotophase it was 63.12% males and 76.25% females. Peak emergence of males was observed at 4 pm with 11.88% during photophase but for female it was 9.38% during scotophase. There was peak emergence at 10 pm for females with 26.25% but for males, it was 17.5%. Another small peak of emergence was observed during 2-3 am (scotophase) with18.12%

Fig. 1 A. Male moth with forked abdomen tip

Fig. 1 B. Female with tapered abdomen

Table 1. Mean emergence pattern of *M.vitrata* (N=160 F=80; M=80)

Time of emergence (0-24h)	Mean% of male moths emerged	Mean% of female moths emerged
6:00 am	0	0
7:00 am	0	0
8:00 am	0	0
9:00 am	0	0
10:00 am	0	0
11:00 am	0	0
12:00 pm	0.625	0
1:00 pm	5.625	1.875
2:00 pm	10	7.5
3:00 pm	8.75	5
4:00 pm	11.875	9.375
5:00 pm	0	0
6:00 pm	2.5	0
7:00 pm	6.25	8.125
8:00 pm	1.875	3.75
9:00 pm	0	0
10:00 pm	17.5	26.25
11:00 pm	2.5	1.25
12:00 am	1.875	0
1:00 am	5	5.625
2:00 am	9.375	11.875
3:00 am	8.75	11.25
4:00 am	7.5	8.125

for males and 23.12% for females. For males, least percentage of emergence recorded with 5.63% at 1 pm (photophase) and 2.5% at 6 pm during scotophase, whereas for females least emergence recorded with 1.25% at 1 pm of photophase and 11 pm of scotophase (Table 1).

Calling pattern of one to eight day old moths were observed. Calling was initiated during 2nd hour of scotophase and reached maximum at 6th hour of scotophase in third day old moth**.** Calling females of *M. vitrata* were correlated with their age. There was no calling observed during the first hour of scotophase irrespective of the moth age. Single calling peak was observed at sixth hour for the moths of all age groups except for three day old where additional peak of calling at 5th and 7th hour of scotophase were observed. There was gradual reduction from fourth, fifth, sixth, seventh and eighth day old moths (26.25; 16.67; 11.67, 5 and 3 %). Similar trend of calling were recorded in all age groups of moths. There was minimum percent of calling in initial hours and gradually increase in proceeding hours. However, there was a decrease after 7th hour of scotophase. Peak calling of 43.5 % was recorded in three-day-old moths during sixth hour of scotophase, which was statistically significant from four-day-old moths. The female calling percentage was maximum during 6th hour of scotophase (11 pm) for one to eight day old females (Table 2).

The response of *M. vitrata* males to calling females was signalized by constant antennal swing,

Table 2. Calling behaviour of one to eight day old *M. vitrata* moths in different scotophase periods with percent of calling females

Age of females	6pm	7pm	8pm	9pm	10pm	11pm	12pm	1am	2am	3am	4am	5am
One day old	0 (00)	1.3 (1.67)	4.3 (5.42)	7 (8.75)	9 (11.17)	13 (14.58)	10.3 (12.92)	7.3 (8.75)	2.6 (3.33)	0 (00)	0 (00)	0 (00)
Two day old	0 (00)	6 (7.50)	11.6 (14.58)	16.3 (20.42)	15 (24.58)	23.6 (31.67)	23 (29.58)	19.3 (22.50)	12.3 (15.42)	0.6 (0.83)	0 (00)	0 (00)
Three day old	0 (00)	0 (7.50)	6 (12.92)	10.3 (23.33)	20.3 (39.58)	31.6 (43.75)	35 (38.33)	33 (40.00)	34.3 (21.25)	17 (00)	0 (00)	0 (00)
Four day old	0 (00)	4.3 (5.42)	7.6 (9.58)	10.3 (12.92)	17.6 (22.08)	21 (26.25)	15.6 (19.58)	13 (15.00)	8 (10.00)	0 (00)	0 (00)	0 (00)
Five day old	0 (00)	1.3 (1.67)	6 (5.83)	77.3 (8.75)	10.3 (12.92)	13.33 (16.67)	11.33 (14.17)	8.66 (10.42)	6.6 (7.08)	0 (00)	0 (00)	0 (00)
Six day old	0 (00)	0.3 (2.5)	3.6 (4.17)	5.33 (5.83)	7 (9.17)	15 (11.67)	11.6 (7.92)	9 (5.42)	3.3 (4.17)	0 (00)	0 (00)	0 (00)
Seven day old	0 (00)	0.3 (00)	1.6 (1.25)	3.6 (2.92)	5.33 (3.75)	6.66 (5.42)	3 (2.50)	2.6 (1.67)	2 (0.420	0.00	0 (00)	0 (00)
Eight day old	0 (00)	0 (00)	0 (00)	1.6 (1.67)	2.3 (2.08)	2.6 (2.92)	1.6 (1.67)	1.6 (0.42)	0.3 (00)	0.00	0	0

Values parentheses are in percentage

Table 3. Details of mating pattern of *Maruca vitrata*

Age of moths	No of pairs observed	No of pairs mated	Time of pairing	Duration of mating	Percentage of mating
One day old	15	0	0	0	0
Two day old	15	2	11:15 pm	45 min	16.6
Three day old	15	4	12:15 pm	60 min	26.6
Four day old	15	1	1:00 pm	45 min	6.6
Five day old	15	0	-	-	0
Six day old	15	0	-	-	0
Seven day old	15	0	-	-	0
Eight day old	15	0	-	-	0

movement of their head in circular manner, rubbing of legs and exposed hair pencil. Before commencement of mating, males advance towards females from sideways and over the body and get close by walking. Whereas female settled down at the base of substrate wall. Once paired, they pose their body in opposite direction. Highest mating frequency was occurred in 2nd and 3rd day old moths during 11-12th hour and 12-13th hour respectively (Table 3).

DISCUSSION

Luo *et al.* (2004) reported that adult emergence of lepidopterans did not occur in precise time of the day, as moths were sensitive to the external factors of the environment like temperature and photoperiod. They also observed that the daily emergence rhythm for *Liriomyza huidobrensis* and *L. sativae* is strongly influenced by temperature. As temperature increases, the emergence period are shortened. However, the peak emergence for females was more than males during photophase. In another study Lu *et al.* (2007) showed that *M.vitrata* emergence was seen throughout the day under 14L: 10D condition in which 73% of males and 86% of females emerged during scotophase.

In lepidopterans, the calling behaviour and mating behaviour are age dependent and maintained by a circadian rhythm that is usually influenced by exogenous factors (photoperiod and temperature) and physiological factors (Turgeon and McNeil, 1982).The extrusion of theovipositor beyond the abdominal tip to expose the pheromone glands is the main sign of the calling posture, as in case of other lepidopterans (West *et al.,* 1984). The pattern of calling is different in other moth species such as *Sesamia nonagrioide*s (Schal *et al*., 1987) and *Virbinia lamae* (Babilis and Mazomenos, 1992) where with increase in age, there was increased calling percentage. This dissimilarity might be due to the physiological difference in different species.

The third day old *M. vitrata* showed highest mating percentage with 26.6% and second day old moth showed 16.6% of mating and least mating percentage recorded for fourth day old moths (Table.3). A similar result was obtained for the study conducted by Huang and Peng (2001) and Lu *et al*. (2007) on *M. vitrata* where highest mating frequency was found on 3rd night after emergence. However, mating of most nocturnal moths occurred during scotophase and very few of them reported on latter phase of the photophase and scotophase.

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Dialeurodes pongamiae - A new species of whitefly (Hemiptera: Aleyrodidae) from India

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ABSTRACT: A new whitefly species, *Dialeurodes pongamiae* breeding on *Pongamia pinnata* from Bengaluru (Karnataka: India) is described and illustrated.

KEYWORDS: Aleyrodidae, *Dialeurodes*, *Pongamia pinnata*

During the course of a survey in 2012 a whitefly breeding on *Pongamia pinnata* in Bengaluru (Karnataka, India) was collected and found to be new to science. It is described with illustrations as a new species *viz., Dialeurodes pongamiae*.

***Dialeurodes pongamiae* sp. nov.** (Figs. 1 - 4)
LSID urn:lsid:zoobank.org:act:F9D74306-32F8-4874-BBAB-E428EB32C8F7

Puparium: White, without wax secretion; elliptical, anterior region more narrowed than posterior region and oval, broadest at first abdominal segment region; 1.22 - 1.31 mm long and 1.01 - 1.12 mm wide; found singly and scattered one or two per leaf on the under surface of leaves.

Margin: Margin crenulate, 17 – 18 crenulations in 0.1 mm, thoracic and caudal tracheal pore regions indicated as invaginated clefts with chitinized rim having internal teeth. Anterior and posterior marginal setae each 7 µm long.

Dorsum: Submargin with tubular ridges having granules; subdorsum with semi-circular shaped microtubercles, arranged in rows; submedian area smooth. Abdominal and thoracic segment sutures distinct extending up to inner sub dorsal area. Submedian pockets present in abdominal segment sutures I – VII. Longitudinal moulting suture reaching margin and transverse moulting suture bends upwards on submedian area and reaching outer subdorsum. Five rows of germinate pores on sub dorsum, a row each of pores and porettes on submargin and submedian area. Thoracic tracheal furrows indicated. Caudal tracheal furrow funnel shaped 208 µm long, 20 µm wide at its widest end.

Chaetotaxy: Four pairs of minute pointed setae-cephalic, first abdominal, eighth abdominal setae cephalolaterad of vasiform orifice and submarginal caudal setae posterior-laterad of caudal furrow each 2µm long. Subdorsum with a row of 12 pairs of minute pointed setae, each 5 µm long..

Vasiform orifice: Subcircular, as long as wide, (39 - 41 µm), lateral and posterior wall of orifice, with a

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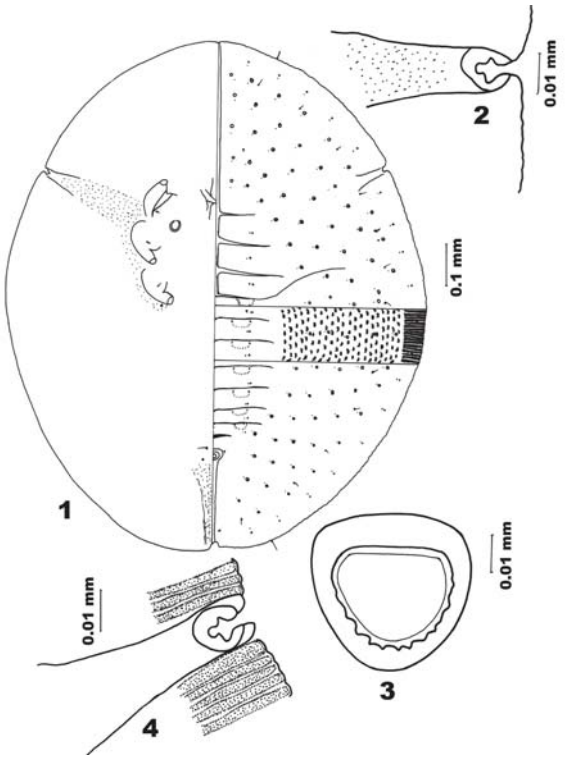

Figs. 1 - 4. Line diagram, *Dialeurodespongamiae* sp. nov. 1. Puparium, 2. Thoracic tracheal fold with stipples, 3.Vasiform orifice, 4. Margin at thoracic tracheal pore region

comb of inner teeth; operculum subcordate, wider than long broader at the anterior and narrows posteriorly, 21 - 25 µm long, 24 - 28 µm wide, filling entirely the orifice and obscuring lingula.

Venter: Paired ventral abdominal setae 12 µm long, 52 µm apart. First and eighth abdominal spiracles visible. Thoracic and caudal tracheal folds distinct with stipples, stipples at the thoracic fold extending upto the end of metathoracic legs. Antennae reaching base of prothoracic legs. Base of pro, meso and metathoracic legs each with a pair of minute setae, 3 µm long. Adhesive sacs visible.

Material examined: Holotype **-** India: Karnataka: Bangalore, one puparium, mounted on slide, on *Pongamia pinnata*, 10.i.2012, R. Sundararaj, will be deposited in the collection of National Bureau of Agricultural Insect Resources (NBAIR), Bangalore, India. Paratypes: 11 mounted puparia, data same as holotype, deposited one each in the collections of National Forest Insect Collection, Forest Entomology Division, Forest Research Institute, Dehradun (NFIC# 22063); Zoological Survey of India, Kolkata (5644/H15) and the remaining in the collection of Institute of Wood Science and Technology, Bangalore.

Host: *Pongamia pinnata.*

Distribution: India: Karnataka.

Etymology: Named after its host plant genus

Comments: This species resembles *D. loganiacei* Pushpa & Sundararaj in the presence of dense microtubercles and row of minute setae on subdorsum. It also resembles *D. sepangensis* Corbett in shape, thoracic and caudal tracheal pore regions with internal teeth, a row of minute setae and anterior curving of transverse moulting suture but differs from it in colour, crenulate margin, operculum entirely filling the orifice, lingula concealed and by the presence of semi-circular shaped microtubercles on subdorsum.

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Short Communication No. ent. 44110

First report of *Macrochenus guerinii* (White 1858) (Cerambycidae: Lamiinae) from Maharashtra, India

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ABSTRACT: The occurrence of *Macrochenus guerinii* (White 1858) (Lamiinae: Cerambycidae) is reported for first time from Maharashtra, India.

KEY WORDS: *Macrochenus guerinii,* Cerambycidae, Maharashtra

Indian Cerambycidae comprise 1536 species and 440 genera under 7 subfamilies (Kariyanna *et al.,* 2017). The state of Maharashtra represented by 68 species of Cerambycidae (Ghate, 2012). *Macrochenus guerinii* (White 1858) (Lamiinae; Cerambycidae) was collected from light source of college campus of R.B.M. Mahavidyalya, Chandgad, Maharashtra (latitude 15° 57. 493' N and longitude 74°10. 028'E). Apart from referring to Kumawat *et al.* (2015) and *http://www.cerambycoidea.com* for identification, the identity of the insect was confirmed by Dr. Hemant Ghate. The description of *M. guerinii* in this study is as follows-

Macrochenus guerinii (White, 1858)
(Plate 1 A - D and Plate 2 E - F)

Pelargoderus guerinii White, 1858 *Ann. Mag. Nat. Hist*. **3**, 2: 274.

Specimens examined: One female, 3.v.2017, light trap, R. B. M. Mahavidyalya Chandgad, (elevation 710m), Kolhapur, Maharashtra, India, Coll. S. V. More, identified by Dr. Hemant Ghate (host plant unknown)

Adult (female): Body length: 23.8mm; width: 4.8mm. Head gray covered with scattered few gray hairs with 4 parallel black stripes; the 2 dorsal black stripes present behind each basal segment of antennae, other 2 black stripes present in the lateral side of each eye (plate 1. A, C, D and E), a triangular black spot present between the eye (plate 1. D), Antennae black covered with grayish white colour hairs, the basal joint of each antennae very small as compared to other segments, the apical segment longer than segment number 8 and 9 and the tip slightly pointed. Vertex gray without puncture , pronotum gray without spine, and longer than head, covered with 4 parallel black stripes, dorsal 2 black stripes extending to the basal segment of each antennae and lateral stripes joined to the each eye, and its prosternum black colour, discrimen gray and black stripe present on metaventrite; the elytron gray coloured with large black spots on its

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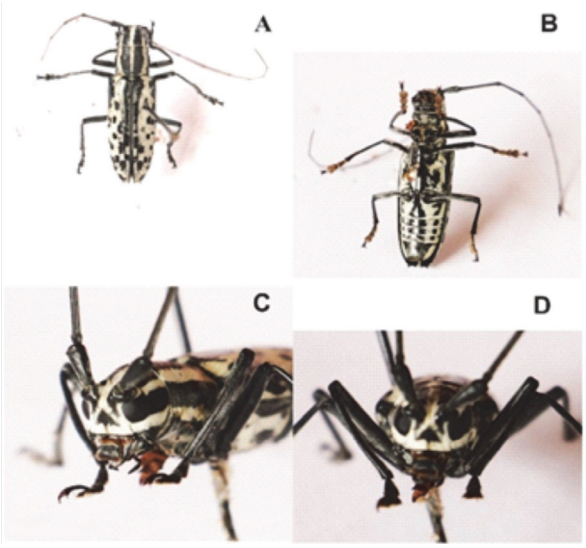

Plate 1. *Macrochenus gurini* - Morphology
A: dorsal view; B: ventral view; C: head lateral view; D: head front view

Plate 2. *Macrochenus gurini* - Morphology
E: lateral view details; F: head details

anterior margin or near the base of each elytron and one on the middle, remaining portion covered with small, slightly large, circular, semicircular spots scattered in irregular shape (Plate 1 A), scutellum semicircular gray, apex of each elytron blunt with spines. Abdomen ventrite gray, with parallel black stripes; maximum area of ventrite five covered with black colour (Plate 1 B). Legs black, tarsus brownish; claws widely separated and covered with brownish hairs with blunt spine present on dorsal surface of each tibia.

Distribution: Bangladesh, Laos, Myanmar, Nepal, Thailand, Vietnam China and India (Assam, Meghalaya, Sikkim, Tripura West Bengal and Arunachal Pradesh).

Remarks: This is the first report on the occurrence of *Macrochenus guerinii* from Maharashtra.

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http://www.cerambycoidea.(accessed on 21/01/2019)

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