ISSN 0377- 9335

ENTOMON

Volume 43 SEPTEMBER 2018 Number 3

FOUR DECADES OF EXCELLENCE

ASSOCIATION FOR ADVANCEMENT OF ENTOMOLOGY
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ENTOMON

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First report of *Aedes japonicus japonicus* Theobald (Diptera: Culicidae) from India with special reference to the effect of temperature and relative humidity on its larvae

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ABSTRACT: *Aedes japonicus japonicus* Theobald, 1901 an invasive mosquito species is a competent vector of West Nile virus, La Crosse virus and Japanese Encephalitis virus. Environmental parameters such as temperature and relative humidity affect the life cycle of mosquitoes. The length of the developmental stages has been found to vary inversely with an increase in temperature and relative humidity. The effects of habitat and weather parameters on this mosquito are not well documented. Therefore investigations were carried out to identify the larvae and adults of *Ae. japonicus japonicus* and probe the effect of temperature and relative humidity on its larvae. We found by regression analysis that the weather parameters (temperature and relative humidity) and the larval count were positively correlated. Subsequently a one way ANOVA proved that the larval count varied significantly with these two parameters. The maximal larval count was obtained in the temperature range of 25.5 and 37.5°C with the highest at 28.5°C. The relative humidity range of 51.5 to 81.5% supported a high larval count with the maximum count being obtained at 72.5%.

KEY WORDS: Invasive mosquito, life cycle, larval count, weather parameters

INTRODUCTION

Mosquito borne diseases affect a large portion of the world's population being mostly prevalent in the tropical countries. Mosquitoes serve as vectors of many diseases like malaria, yellow fever, dengue fever, chikungunya fever, filariasis etc. *Aedes japonicus japonicus* Theobald, 1901 is enlisted as one among the top hundred invasive mosquitoes. Though the mosquito is endemic to Korea, Japan, Taiwan, Russia and southern China but, it is now also being reported to be found in parts of Europe, New Zealand, Canada and U.S.A. The larvae are slender and appear brownish-yellow or darker in color with a long siphon (Kampen *et al*., 2012). They are found in a variety of natural and artificial aquatic habitats like rock pools, tyres, bird baths, tree holes etc with varying sunlight, elevation and detrital content (Andreadis *et al*., 2001 and Lorenz *et al*., 2013). Adults are relatively large with golden scales on the scutum and are found in forested areas (Andreadis *et al*., 2001). They are active during the daytime and crepuscular hours with the females feeding preferentially on mammals (Turell *et al*., 2005). *Ae. japonicus japonicus* is a known vector of West Nile virus in U.S.A (Andreadis *et al*., 2001;

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Turell *et al*., 2005). Apart from this, laboratory studies have shown it to be a competent carrier of Japanese encephalitis virus (Takashima and Rosen 1989) and La Crosse virus (Sardelis *et al*., 2002). The mosquito is also a moderately effective vector of Saint Louis encephalitis virus (Sardelis *et al*., 2003), Eastern equine encephalitis virus (Sardelis *et al*., 2002), Chikungunya virus, Dengue virus (Schaffner *et al*., 2011) and Rift Valley fever virus (Turell *et al*., 2013).

Temperature and relative humidity affect the stages of the life cycle of *Aedes* sp. The length of these stages has been found to be inversely proportional to increment of these weather parameters. The ambient temperatures range between 20°C and 36°C for successfull completion of its life cycle (Marinho *et al*., 2016). At 35°C mortality is higher in environments with high nutrient concentration (Farjana *et al*., 2012). Intensity of the temperature effect is influenced by relative humidity. High relative humidity supports survival of female mosquitoes and is responsible for higher egg production (fecundity) (Costa de Almeida *et al*., 2010). Females of *Aedes* sp. have significantly higher oviposition rates at 84% relative humidity than those at 34% relative humidity (Canyon *et al*., 1999). Hatching rates of the eggs of *Aedes* sp. is directly proportional to relative humidity values (Costa de Almeida *et al*., 2010). Fecundity, oviposition rates and hatching rates determine the larval counts in the habitat. Thus a study on the effect of change in temperature and relative humidity on the larval counts of important genera of mosquitoes will contribute towards the understanding of their population dynamics and help in developing effective vector-control programmes. The work embodied in this paper probes the effect of change in the temperature and relative humidity on the larval count of *Ae. japonicus japonicus* during the period August, 2015 and August, 2017.

MATERIALS AND METHODS

Collection of larvae: Mosquito larvae were collected as per the protocol (Chakraborti and Bandyopadhyay, 2017) from Hoogly district of West Bengal, India. The Hoogly district in West Bengal, India spans between the coordinates; 22.8963° N, 88.2461° E covering an area of 3149 sq. Km. Larvae were brought for identification to the Parasitology laboratory at the Department of Zoology in the University of Kalyani, Kalyani,West Bengal, India. A total of seven samples were collected every month during the period of study between August, 2015 and August, 2017.

Determination of temperature and relative humidity: The temperature (°C) and relative humidity (%) values were recorded on days of sample collection using a portable thermometer hygrometer every month. The averages of these temperature and relative humidity values were used for the study.

Identification of larvae and determination of larval count: Identification of the mosquito larvae was performed by studying their body parts under the 10X objective of a phase contrast microscope (Olympus Corporation, Model: KH). The work of Farajollahi and Price (Farajollahi and Price, 2013) was followed for identification. Larval counts per sample were determined. The temperature (°C), relative humidity (%), mean larval count (M), standard deviation (SD) and standard error of mean (SE) was determined on a monthly basis throughout the period of study (Table 1). The Graph Pad software (http://graphpad.com/quickcalcs/CImean1/) was used to calculate mean larval count (M), standard deviation (SD) and standard error of mean (SE) throughout.

Identification of adults: The larvae were reared at 27±2°C, 75% relative humidity in a photoperiod of 12h light and 12h dark. They were fed a diet comprising of yeast extract and finely ground dog biscuits in the ratio 1:3 to obtain adults. The adult pictorial keys by William W. Stanuszek of the Saginaw County Mosquito Abatement Commission (Stanuszek, 2013) were followed for identifying the adults.

Determination of optimal temperature and relative humidity for maximal larval count:

Ungrouped data was organized into three continuous temperature classes and seven continuous relative

Table 1. Temperature (°C), relative humidity (%), mean larval count (M), standard deviation (SD) and standard error of mean (SE) as obtained during the period of sampling (M, SD and SE were calculated using Graph Pad software)

Sampling period	Temperature (°C)	Relative humidity (%)	Meanlarval count	Standard deviation	Standard error of mean
Aug'2015	31	75	94.86	15.83	5.98
Sep'2015	32	68	100.14	12.48	4.72
Oct'2015	31.5	63	95.71	10.84	4.10
Nov'2015	28	52	91.29	9.55	3.61
Dec'2015	25	43	47	4.51	1.70
Jan'2016	26.2	41	50	7.92	2.99
Feb'2016	28.4	50	63.71	8.26	3.12
Mar'2016	31.8	51	80.43	9.8	3.7
Apr'2016	35	50	61.43	8.77	3.32
May'2016	35	58	56	9.73	3.68
Jun'2016	34.2	62	69	7.85	2.97
July'2016	32	68	94.57	11.31	4.28
Aug'2016	30.8	76	95.57	11	4.16
Sep'2016	31.2	81	94.14	11.39	4.31
Oct'2016	28.7	71	94.86	10.87	4.11
Nov'2016	26	56	78.57	10.89	4.12
Dec'2016	24.5	45	52	8.33	3.15
Jan'2017	20.1	40	40.14	7.13	2.69
Feb'2017	23	41	53.29	5.19	1.96
Mar'2017	28	57	74.86	9.56	3.61
Apr'2017	32	65	83.57	7	2.64
May'2017	33	70	84.14	7.93	3
Jun'2017	32.3	78	82.43	12.49	4.72
July'2017	31.2	69	94.29	14.29	5.40
Aug'2017	32	72	96.71	13.06	4.94

humidity classes. For determining the optimum temperature and relative humidity which yield maximal larval count, larval counts (M±SE) (values corresponding to the different classes of temperature and relative humidity) were plotted against the temperature and relative humidity values corresponding to the class marks (mean of the upper class limit and lower class limit) of the respective classes.

Regression analysis was done using the Graph Pad software (http://graphpad.com/quickcalcs/linear1/) to probe any correlation between the dependent (larval count) and independent (temperature and relative humidity) variables. A one-way ANOVA was performed to ascertain that the variation of larval count with temperature and relative humidity was significant. Test of homogeneity of variances was performed using the Levene's test. Data analysis

was performed using the SPSS software (version 19).

RESULTS AND DISCUSSION

Identification of larvae and adults:

The larval specimen was slender and dark brownish-yellow in appearance with a big siphon and the details of the larval body parts was identified under the 10X objective of a phase contrast microscope (Table 2, Fig. 1). It was identified as a larva of *Ae. japonicus japonicus* by following the pictorial keys of Farajollahi and Price (Farajollahi and Price, 2013). The adult specimens were dark in appearance with golden scales on scutum. They were identified as adults of *Ae. japonicus japonicus* (Fig. 2) by following the adult pictorial keys of William W. Stanuszek (Stanuszek, 2013).

Determination of optimal temperature and relative humidity for maximal larval count:

A high larval count (M±SE) was obtained in the temperature range of 25.5 to 37.5°C with the maximal larval count being obtained at 28.5°C. The larval count (M±SE) was high in the relative humidity range of 51.5 to 81.5% with the maximum number of larvae surviving at 72.5% (Fig. 4).

Regression analysis established a positive correlation between the dependent (larval count) and independent (temperature and relative humidity) variables (Fig. 3). Regression analysis showed that the larval count significantly varied with change in temperature and relative humidity with the regression equation, r^2 and p values for larval count versus temperature being $y = 2.705x-3.242$, $r^2 = 0.2985$, $p = 0.0047$ and that for larval count versus relative humidity being $y = 1.255x+1.777$, $r^2 = 0.7076$, $p<0.0001$ respectively.

The one way ANOVA proved that the larval count varied significantly with the temperature (ºC) and relative humidity (%) (p value < 0.05). Levene's test of homogeneity of variances for both temperature and relative humidity signified that the variances among the different classes of temperature and relative humidity were homogeneous. The p values for the Levene's test for temperature and relative humidity were 0.205 and 0.064 respectively.

The study was conducted on the effects of the two environmental parameters namely, temperature and relative humidity on the larval count of *Ae. japonicus japonicus*. The Hoogly district in West Bengal, India experiences a tropical wet and dry climate. The temperature (values corresponding to

Table 2. Comparing the larval body parts of the specimen to the one studied by Farajollahi and Price

Larval body parts of *Aedes japonicus japonicus*	Body parts as described by Farajollahi and Price	Remarks: Present or Undetected in the test specimen
Head hair	Straight line arrangement	Present
Upper head hair 5-C	Multiple	Present
Lower head hair 6-C	Multiple	Present
Preantennal 7-C	Multiple	Present
Pecten teeth	Distally detached	Undetected
Comb scales	Within pecten patch	Present
Anal saddle	Heavily spiculated	Present
Siphonal tuft 1-S	Multiple	Present
Lateral hair 1-X	On saddle, single	Present
Anal papillae	Equal and tapering	Present

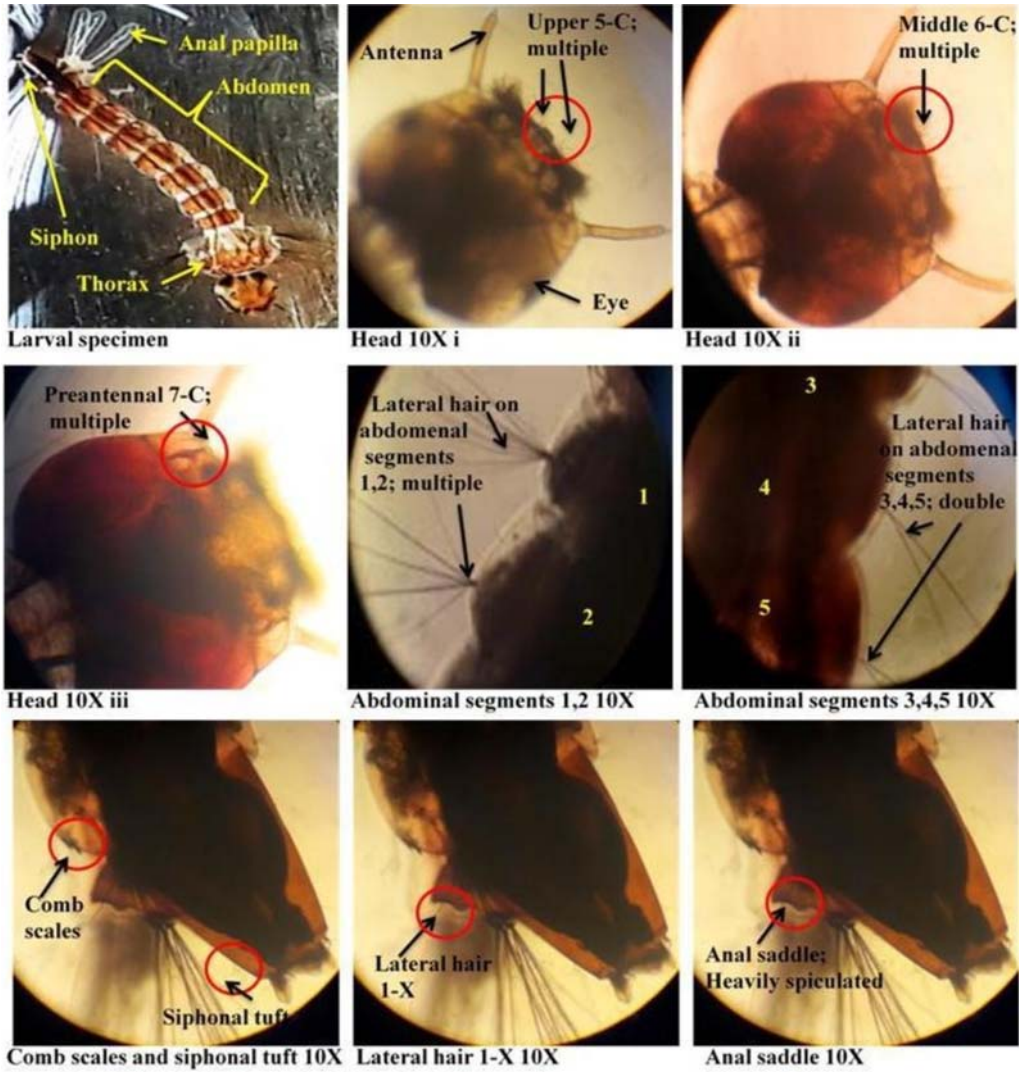

Fig. 1. Features of the body parts of the larva as seen under the 10X objective of a phase contrast microscope

the class marks of temperature classes) in this district ranges between 22.5°C and 34.5°C which is approximately close to that of the average monthly temperatures varying between 19°C and 30°C (Khan *et al*., 2017) in the neighbouring regions. It has been established that the time taken for life cycle completion and temperature are related inversely (Beserra *et al.,* 2009). Although the larval count varied significantly with temperature ($p<0.05$) but a decrease in the larval count was observed above 28.5°C as evident from the study. This may have been due to suppressed development of the embryo. Rise in temperature above the optimum temperature does not decrease the rate of development to a large extent. The rate of development may decrease slightly until the temperature reaches an upper limit of around 38°C to 42°C (Eisen *et al*., 2014). High humidity along with optimum temperatures promotes female survival, fecundity and hatching rates (percentage of larvae produced from total eggs (% of larvae ± SE). The oviposition time is affected by temperature irrespective of relative humidity (Canyon *et al*., 1999; Costa de Almeida *et al*., 2010). A study conducted on *Ae. aegypti* mosquito (Costa de Almeida *et al*., 2010) showed that the females survived for 11 days at 25ºC, 80% relative humidity producing 99.08 ± 3.56 eggs (M±SE) and only for

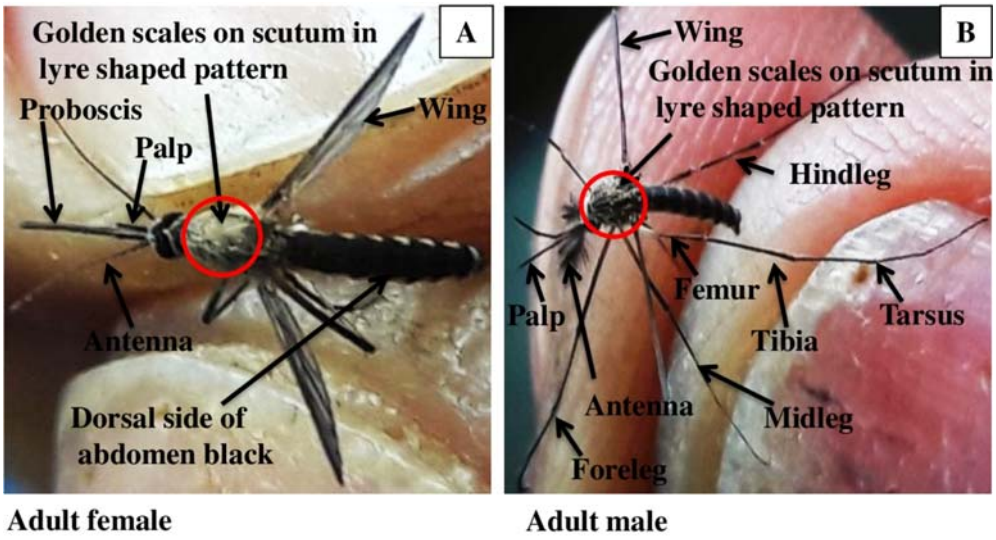

Fig. 2. Features of the body parts of the adult specimens as observed

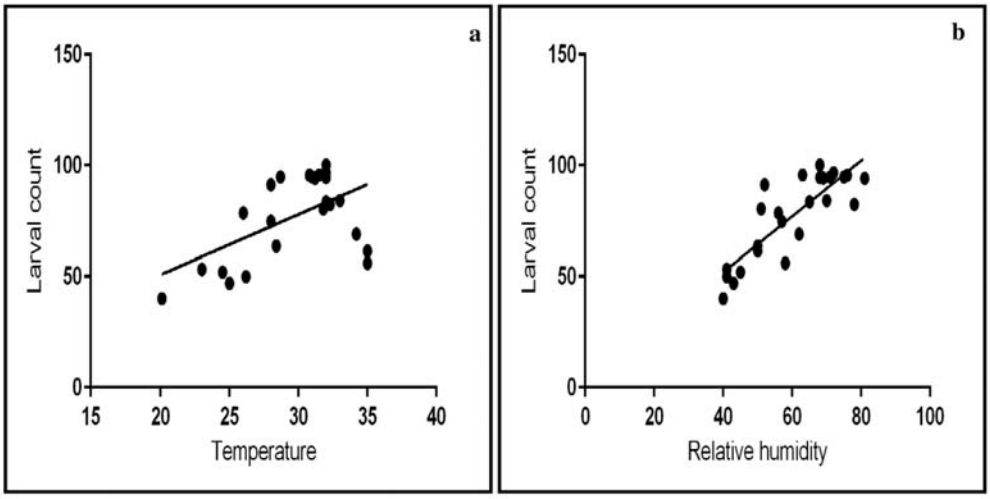

Fig. 3. Regression analysis between the dependent (larval count) and independent (temperature and relative humidity) variables

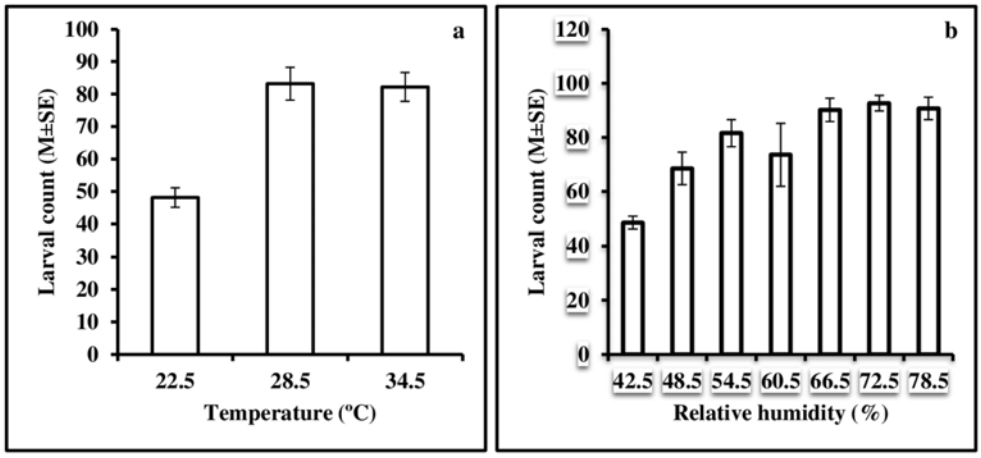

Fig. 4. Larval count (M ± SE) versus temperature (ºC) and relative humidity (RH) (%)

8 days at 25ºC, 60% relative humidity producing 85.99 ± 3.16 eggs (M±SE). Females survived for 7 days at 30ºC under both the conditions of relative humidity producing 75.75 ± 5.03 eggs (M±SE) at 80% relative humidity and 82.89 ± 3.33 eggs (M±SE) at 60% relative humidity. At 35ºC females survived for 5 days under both the humidity conditions although 20.9% females survived at 80% relative humidity and 12% survived at 60% relative humidity. The number of eggs (M±SE) produced were 59.62 ± 3.41 at 35ºC, 80% relative humidity and 54.53 ± 4.81 at 35ºC, 60% relative humidity. The percentage of larvae obtained from eggs (hatching rate) at 60% humidity reduced slowly with an increase in temperature. At 60% relative humidity eggs subjected to 25ºC produced about 10 and 20% more larvae than eggs at 30 and 35°C. At 80% relative humidity, hatching rates remained similar at 25 and 30 ºC i.e. 58.88 ± 4.87% and 70.67 ± 5.56% with a significant reduction at 35 ºC i.e. 43.08 ± 5.89 suggesting that optimum temperature and high relative humidity promotes higher female survival, fecundity and hatching rates. Oviposition time was 8 days at 25ºC, 6 days at 30ºC and 5 days at 35ºC irrespective of relative humidity. These findings corroborate our results i.e. the larval count varies significantly with the temperature and relative humidity (p value < 0.05) within temperature range of 22.5 to 34.5°C (class marks of temperature classes) and relative humidity range of 54.5 to 78.5% (class marks of relative humidity classes). The maximum number of larvae survived at 28.5°C and 72.5% relative humidity.

ACKNOWLEDGEMENT

The authors thank the Department of Zoology, University of Kalyani for the infrastructural facilities to carry out this research work.

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(Received 20 July 2018; revised ms accepted 05 September 2018; published 10 October 2018)

ENTOMON 43(3): 157-164 (2018)
Article No. ent. 43302

Drying fish preference assessment and efficacy of semiochemicals as repellents to blow fly *Chrysomya megacephala* (F.) (Diptera: Calliphoridae) during sun drying of fish

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ABSTRACT: *Chrysomya megacephala* (F.) is a major pest of fish after harvest and during the processing stage. Existing management strategies are inadequate in curbing the fly menace especially in processing sites with poor hygenic conditions. The present study attempted to evaluate the preference of the *C.megacephala* in drying fish stages and also evaluated the efficacy of synthetic compounds of some fish based semiochemicals which are identified as repellents. The results of the study indicate that salt cured fish after one- day drying is the most preferred choice for the flies. All synthetic repellents attempted to control the flies, were found to be effective as repellents and had given about 50% suppression of the population compared to control. Urethane (Ethyl carbamate) had shown the maximum repellency (67%) followed by Hexanal (52.6%) and Diphenyl ether (52%). Dimethyl benzothiophene and N, N-dimethyl acetamide also exhibited 43.3 % to 48.2% repellency in alleviating the flies. Results of the preference study provide information to processors about right time to take adequate precaution while sun drying of fish. The study also revealed the possibility of utilising tested synthetic analogues in population suppression of blowflies with an effective dose optimisation before application.

KEY WORDS: *Chrysomya megacephala*, pest of dry fish, stage preference, repellency

INTRODUCTION

Associated with agriculture and allied production, fisheries play the role of critical contributor to food supply in terms of economic and social security with nutritionally significant animal protein. Fish is a highly perishable commodity and undergoes step by step spoilage and loss after harvest. According to Gethu *et al.* (2016) physical losses that occur due to under-utilization after landing, losses in nutritional value due to decomposition, quality losses that occur due to spoilage, market force loss due to inadequacy

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between demand and supply, losses due to traditional processing methods and losses due to insect infestation which contribute to physical and quality loss are the various forms of post- harvest losses that occur. Under the influence of hot and humid conditions of tropical countries, insect infestation and other biological agents contribute to large scale physical losses and quality deterioration of processed fish (Khan and Khan, 2001). The pest species complex which incur loss to the sector is dominated by blowflies (Diptera: Calliphoridae), flesh flies (Diptera: Sarcophagidae) and hide beetles (Coleoptera: Dermestidae and Cleridae) (Johnson and Esser, 2000). Each insect group attacks the fish at various stages in the processing and storage of which blowflies are attracted to the fish after harvest, during the salting and sun-drying stages.

After harvest, 1-2 day old fish is highly preferred for oviposition and breeding blow fly *C. megacephala*, the major pest of fish and other blowflies (Nowsad, 2010).The existing management strategies have not yielded any effective result to overcome the menace. The present study aims to evaluate the preference of *C. megacephala* towards the drying stages of fish and also attempts to evaluate the effectiveness of some identified fish based semiochemicals as repellents against blowflies during sun drying of fish. These semiochemicals were identified from post mortem and salt cured and sundried stages of Indian mackerel by headspace gas chromatography mass spectrometry (HS-GCMS) studies and the related repellency behavior of blow fly *C. megacephala* are determined by electroantennographic and olfactometer bioassay studies.

MATERIALS AND METHODS

Preparation of dry fish samples and preference study:

Indian Mackerel (*Rastrelligar kanagurta*) was procured from local fish markets of Cochin. The fish samples of different drying stages used for study were prepared by dry salting method. Dry salting (i.e., a layer of fish followed by layer of salt) was done with 25% (w/w) salt for 24 hrs. The samples were then sun dried and designated as salt cured fish without drying (SCF) salt cured and 1 day dried fish (SCDF 1D), salt cured and 2 day dried fish (SCDF 2D), salt cured and 3 day dried fish (SCDF 3D) salt cured and 4 day dried fish (SCDF 4D) based on duration of drying and used for further study.

Oviposition preference study was conducted in fly rearing cages. The preference study was conducted as a multiple choice test. About 30 g of the salt cured and different fish samples were placed in Borosil petriplates (9.5cm Ø) and these were randomly placed in the cages each time to avoid any positional effect. Twenty 8-10 day old gravid females and 10 males of *C. megacephala* were released in each cages and allowed to freely oviposit on their choice of different dried fish samples for 6 hrs. The plates were removed after and weight of egg mass deposited on each sample in petriplate was weighed using a digital electronics balance (Sartorius BP 211D). The experiment was conducted in triplicates and repeated three times.

The test insect: A lab reared population of the blow fly *C. megacephala* were used in the present study. They were established in the animal house of Indian Council of Agricultural Research - Central Institute of Fisheries Technology, Cochin (ICAR-CIFT). Initially a few adults were collected from residential complex of CIFT located at Thevara, Cochin (9.9426° N, 76.2986° E) on a fish offal trap. The adults were brought to the animal house of the institute and maintained at 29 ± 2 °C, 60 ± 5 % R.H and photoperiod of 12:12 (L: D) hr., the condition of animal house. Further multiplication was done on the fish (Indian mackerel) as a rearing medium. The adult flies were reared in insect rearing cages (45 × 45 × 45cm) with wood sheet base, glass top, three sides covered with cloth of which two sides were having circular whole fitted with sleeves to facilitate serving of the food and cleaning. The front door of the cage was made of acrylic sheet. Adults were provided with fish, sucrose crystals, and water soaked absorbent cotton in petriplates. Feeding was provided *ad libitum*. Flies were reared for few successive generations, authenticated the species identification by an insect taxonomist and used for the study.

Test chemicals: The synthetic compounds used for testing were procured from chemical companies Sigma Aldrich, Merck and Avra Synthesis.

Evaluation of repellency effect of synthetic analogues of fish based semiochemicals:

The repellency effect of the fish based semiochemicals were evaluated in small fish drying yard following the methodology adopted by Aak *et al.* (2010) and Zhu *et al.* (2017) with modifications. A fish drying yard of size (2m x 2m) was prepared for the study. Polythene sheet was spread on the floor in which gutted fish for drying spread over exposed to sunlight (Plate 1). The semiochemical compound (4 ml) was sorbed on non absorbant cotton fibres in a porous eppendorf tube which served as a dispenser of the volatile, was kept hanging just above the fish (Plate 1) using a thread which was tied on a thread suspended along the drying area. To sample the flies visiting the drying yard, yellow sticky insect traps (Pest Control of India) of (size 50 cm x 25 cm) 2 nos, adhered on a piece of carton were kept hanging at borders of the drying area. The traps were placed for 6 hrs. in the drying yard till sunlight faded. Afterwards, the traps were removed and the number of flies caught on the traps were recorded (Plate 2 & 3). A control plot sampling was done by placing the traps alone over the field. The experiment was duplicated for each compound and repeated twice. The number of flies caught in the trial was counted and determined the mean value. The efficacy of the tested chemicals were determined by calculating the reduction in the number of flies caught in each trial compared to control. The repellency percentage was calculated according to the formula of Mohammed *et al.* (2016).

$$\text{Repellency (\%)} = (Nc\text{-}Nt)/Nc * 100$$

where Nc = No. of flies caught in control and Nt = No. of flies caught in each treatment.

Statistical Analysis: The data analysis was performed in IBM SPSS Statistic version 20. One-way ANOVA at 5% level of significance was performed to compare the means of population of flies trapped in treated and control plots. Tukey's multiple comparison tests were used for post-hoc analysis. The results are expressed as mean ± standard deviation.

RESULTS AND DISCUSSION

Assessment of drying stage fish preference of *C. megacephala:*

Multiple choice preference study of *C. megacephala* conducted with salt cured fish and with successive stages of drying reveals significant differences in their preference. Among the choices, the fish dried one day after a day's salt curing (SCDF 1D) obtained the maximum eggs which was

Plate 1. Drying plot with repellent & trap (Experimental)

Plate 2. Yellow sticky trap with trapped flies (Control)

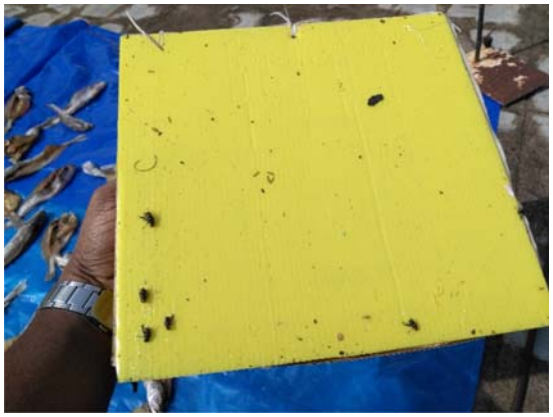

Plate 3. Yellow sticky trap with trapped flies (Experimental)

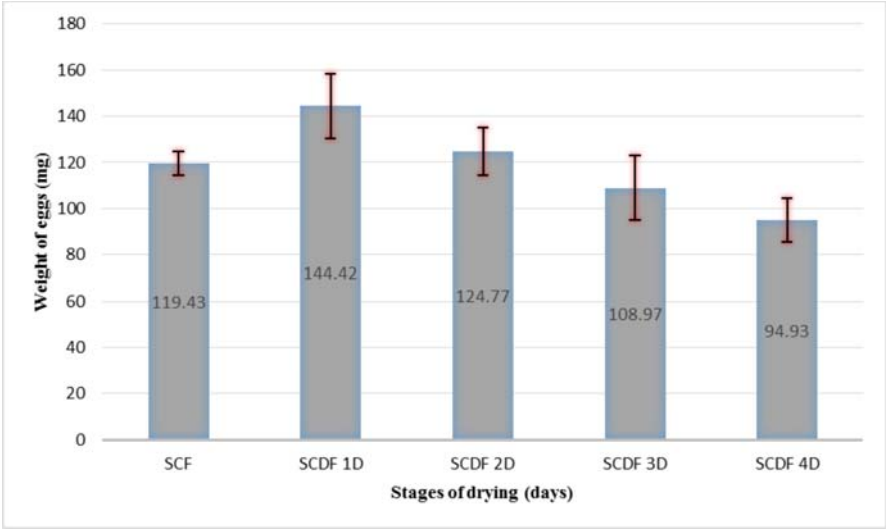

Fig. 1 Oviposition preference of *C. megacephala* on fish drying stage

SCF (Salt cured fish), SCDF 1D (Slat cured and 1day dried fish), SCDF 2D (Slat cured and 2day dried fish), SCDF 3D (Slat cured and 3day dried fish), SCDF 4D (Slat cured and 4day dried fish)

significantly higher compared to others ($p<0.05$). The mean weight of eggs laid on this was 144.42 ± 13.98 mg. The weight of eggs laid on 2 day dried salt cured fish (SCDF 2D) was 124.77 ± 10.53 which also was statistically significant, but was homogenous with SCF ($p>0.05$) where the mean wt. of eggs laid was 119.43 ± 5.13 mg. SCDF 3D and SCDF 4D had obtained the least weight of eggs (108.97 ±14.09, 94.93 ± 9.57 respectively) which was not statistically significant ($p>0.05$) (Fig.1).

The obtained result is in accordance with some of the previous studies conducted by Walker and Wood (1986) and Sachithanandan *et al.* (1986). They reported that during the first two days of sun drying, fish is highly preferred by blowflies and opined that this attraction might be due to the high and preferred moisture content compared to more dried samples. Nowsad (2010) reported a similar effect that fish is more susceptible to blowfly attack during the early stages of drying when moisture content is high. Esser (1988, 1990) observed that in multiple choices, *C. megacephala* preferred to lay eggs on fish with low salt concentration. These facts can be attributed to the obtained result of present study as 1-2 day dried samples will have less salt concentration and more moisture content compared to 3day dried and 4day died samples due to

reduction in water content. Moreover, blowflies possess salt sensitive receptors (Gillary, 1966; Proctor, 1972) which might have enabled them to detect SCDF 1D and SCDF 2D which are with low salt concentrations and high moisture content among the given choices. Esser (1992) and Johnson (1997) reported that salting may result in the production of volatiles which makes fish more attractive to blowflies. Clucas and Ward (1996) also opined that blowflies are attracted to fish visually and by odours or volatile compounds released from the fish. Apart from as a preservative by reducing water activity (a_w) and arrest of microbial growth (Horner, 1997), Harris and Tall (1994) reported that salt enhances the sensory properties such as aroma and flavour in fish foods which also might be the influential factor in the present result.

Efficacy of synthetic analogues of fish based semiochemicals as repellent against blowflies:

Among the five synthetic repellent compounds tested, all had shown effect in reducing the fly population visiting the fish drying yard compared to control which was higher and significant. The most significant reduction in fly number was given by urethane with 67% repellency and a mean no of 18.25 ± 1.0606 flies trapped in. Followed by that, Hexanal and Diphenyl ether, were significantly low from control where the mean no. of flies trapped were 26.5 ± 2.1213 and 26.75 ± 3.8890 respectively with 52.6 and 52.2% repellency and was homogenous. N, N-Dimethyl acetamide and Dimethyl benzothiophene also given significant reduction in fly numbers with 48.2 and 43.3% repellency and a reduction in fly nos. as 29 ± 2.1213 and 31.75 ± 3.1819 compared to control where the mean no. of flies trapped were 56 ± 4.2426, and significantly higher (Table 1).

The initial studies on the repellent effect using common substances on necrophagous insects including blowflies was done by Marchenko (1988) where he reported that paint or gas dropped on clothing induce delayed carrion colonization. The repellency effect of various indigenous oils was tested by Subramanian and Mohanan (1980) against blowflies including *C. megacephala* which revealed that lemongrass oil and camphor in ground nut oil and eucalyptus oil are good repellents. Likewise neem product azadiractin application in drying fish provided more than 80% repellency to *C. megacephala* from fish (Xia *et al.,* 2010). Charabidze *et al.* (2009) reported petroleum spirit, perfume and mosquito repellent citronella has repellency effect on cadaver insects and delay their visiting time while in a closed environment blowfly *Calliphora vicina* has repellency to petroleum spirit, mosquito repellent citronella, hydrochloric acid and paradichlorobenzene. While in the present study purely synthetic compounds of fish based semiochemicals, Hexanal, Diphenyl ether, Urethane (Ethyl carbamate), Dimethyl benzothiophene and N, N-dimethyl acetamide are used as repellents. Angioy *et al.* (1987) previously opined that Hexanal has repellent activity to blowfly *Protophormia*

Table 1. Efficacy of fish based semiochemicals as repellent against blowflies

Semiochemical tested	No. of flies trapped Mean ± SD	Repellency (%)
Hexanal	26.5 ± 2.1213^{b}	52.6
Urethane (Ethyl carbamate)	18.25 ± 1.0606^{c}	67.0
Diphenyl ether	26.75 ± 3.8890^{b}	52.2
N, N- Dimethyl acetamide	29 ± 2.1213^{b}	48.2
Dimethyl benzothiophene	31.75 ± 3.1819^{b}	43.3
Control	56 ± 4.2426^{a}	0

Different superscripts in column indicates significant difference between treatment means ($p<0.05$)

terraenovae and the present study is in accordance with that and Hexanal has given significant repellency effect (52.6%) indicated by the reduction in catch up to 50% compared to control. The repellency effect of Hexanal was identified by Douglas *et al.* (2005) and they reported that a chemical odourant emitted during breeding season of crested auklets *Aethia cristatella*, in which Hexanal is a dominant constituent as it repels mosquitos and other ectoparasites (Douglas *et al.,* 2001, 2005). According to Dethier (1954), Garson and Winnike (1968) there occurs a linear relationship between concentration of aliphatic aldehydes and attraction repulsion behaviour of blow flies. These studies with the result revealed in the present study support the potential of Hexanal to be used as a repellent against blowflies for their management.

Diphenyl ether also provided significant reduction in the number of flies caught in the present experiment indicating the repellency effect of the compound which was 52%. The 50% reduction of the blow flies trapped in the field trap indicate the repellency potential of the compound towards eliminating the flies. The chemical is a reported repellent against insects (Debboun *et al.,* 2006) and Rutledge (1988) had a similar repellency result report with diphenyl ether against mosquitos and horseflies for 3 and 6 hours respectively. Diphenyl ether compounds proved to have knock down effect and mosquitocidal activity to many species (Hueter *et al.,* 2016). Shamsi *et al.* (1990) also evaluated the repellency effect phenyl compounds against blowflies *C. rufifacies* and *Lucilia cuprina* using a modified cone trap method and reported that biphenyl and phenyl phenol provided 70 - 90% repellency effect.

The most significant reduction in fly catch was given by urethane (Ethyl carbamate) among all the synthetic of semiochemicals experimented as repellents. The compound had repellency effect up to 67% and had reduced the fly numbers to three fold in comparison to control field which demonstrates the efficacy and proposes the potential of the compound as a candidate for blow fly management. The repellency effect of ethyl carbamate was reported earlier by Fergusen and Alexander (1953) and substituted carbamate Icaridin (Picaridin) is also a well- known repellent against various insects. Dimethyl benzothiophene and N, N-Dimethyl acetamide are the two other compounds resulted repellency effect with reduction in the no. of flies in sampling compared to control. The repellency or toxicity of the chemical has not been revealed anywhere while it is reported that the derivative benzothiophene is vapour toxic to mosquito *Aedes aegypti* (Koehler and Patterson, 2007) and the presence of benzothiophene with in naphthalene balls which is a well-known insect repellent modifies its toxicity (Pajaro-Castro, 2017). These studies support the results of the present study about the efficacy in repelling blow flies with Dimethyl benzothiophene. Similarly, there are no reports about the repellency effect of N, N- dimethyl acetamide (Acetamide) to any insects. However, it is structurally similar to N, N-diethyl-m-toluamide (DEET) (Snyder *et al.,* 1986) which is an effective repellent to many insects including some blow flies (Zhang *et al.,* 2011). DEET is the active ingredient in many commercial insect repellent products against mosquitoes, flies, ticks, fleas and other biting insects (Rivera-Cancel *et al.,* 2007). So the effective repellency exhibited by the acetamide to blowflies can be attributed due to this structural similarity, which will ensure similar property and it has given about 50% reduction of flies compared to control.

In conclusion, salt cured fish after one day sun drying is the most susceptible stage for blow fly attack. This assessment result would facilitate the traditional fish processors to intervene with remedial measures and take adequate precautions to protect the drying fish. Indiscriminate use of chemical pesticides and use of banned chemicals are reported to be in use for controlling blow flies, where the present study is a preliminary attempt that stands out as novel with the use of synthetics of fish semiochemicals. The data obtained unveils the effectivity of used compounds as repellents that can be utilized further effectively for the blow fly management. All the tested compounds were found effective in reducing the population to 50% or more. However, further dose optimization study at field levels using effective and advance dispensing

system with optimal rate of dispensing are pre requisite for correct evaluation of the effectivity. This would prompt the development of a semiochemical based management strategy to overcome the fly menace in fish drying yards and related areas with poor sanitary conditions.

ACKNOWLEDGEMENT

The authors are grateful to the Director, ICAR-CIFT, Cochin for the support and encouragement provided during the study.

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(Received 21 June 2018; revised ms accepted 13 September 2018; published 10 October 2018)

ENTOMON 43(3): 165-170 (2018)
Article No. ent.43303

Morphology of antennal cleaner in some selected ant species: A scanning electron microscopy study

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ABSTRACT: Antennal cleaners are cuticular structures found in insects like ants which help them in antennal grooming. A well groomed antenna is important for better olfactory sensory perception. Scanning electron microscopy studies on the morphological features of antennal cleaners in some selected ants revealed structural differences like the presence of abundant brushes on the tarsal notches, tarsal comb with abundant tines, and presence of spines among the antennal cleaners of the ants. Differences even if subtle point towards different strategies of antennal grooming adopted by the ants. Bristles, brushes and spines present on the antennal cleaners are components of the antennal cleaner used for different grooming tasks such as adhesion and scraping mechanisms. Further significant differences in the morphometrical features of the antennal cleaners, which probably have a bearing with the life styles of each ants were reported.

KEY WORDS: Ant species, SEM, antennal cleaner, tarsal notches, tibial spur

INTRODUCTION

Insects face the constant challenge to keep their body parts clean from the various types of contaminants they are exposed to from the environment. Bacteria, spores, pollens and inorganic particles like dust, salt adhere to their body parts and interfere with their bodily functions. Therefore for insects, the removal of these micro particles is most important. Grooming help insects to get rid of such particles adhered to their body. In many insects the legs, wings and antenna are modified for the purpose of grooming (Hölldobler and Wilson, 1990). Antennal cleaners in particular, located on the forelegs of ants and other hymenopterans are examples of insect legs and its parts evolved for grooming. They are complex cuticle structures which are modified spurs of tarsus of the legs and possess many components like brushes, bristles and combs which in case of ants, is found effective to remove dust, bacteria, virus, pollen, fungal spores, salt or other particulate matters adhered to the antenna (Szebenyi, 1969; Elawami and Dent, 1995). Adherence of such debris on antennal surface interferes with olfactory sensory perception (Böröczky *et al.,*2013). Each cuticular component of the antennal cleaner is to function in removing particles of different sizes from the antennal surface.

Life style induced adaptations are often reflected in the body parts an insect possess. Antennal

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cleaner though not sensory in function are important fora debris free antennal surface which is important for an efficient sensory perception through the diverse types of antennal sensilla (Reber *et al.,* 2011). Though there have been few studies that help us understand the working mechanism of the antennal cleaner and its structural details in a phylogenetic context (Basibuyuk and Quicke, 1994). Studies relating to the structural modifications of the antennal cleaner in relation to the sensory ecology of ants are few. In the present study we explored the morphological features of the antennal cleaner of a few ants which exemplify contrasting life styles and behaviours. Sensilla profile of the antenna often reflects the life style of the insects and an efficient antennal grooming is important for a better sensory perception. *Diacamma rugosum* (Le Guillou, 1842), *Messor barbarus* (L), *Myrmicaria brunnea* (Saunders, 1842) and *Oecophylla smaragdina* (Fabricius, 1775) ant species were selected for the studies. *O. smaragdina* generally is considered to be an arboreal ant species; *D. rugosum*a generalist forager is commonly found to be foraging in open spaces, gardens and detritus; *M. brunnea* is a subterranean ant species; *M. barbarus* is the granivorous seed harvesting ants (Plowesand Holldobler, 2013; Wriedt *et al*., 2008). Structural modifications of the antennal cleaner reflect different ways of antennal grooming. Though there have been studies on the antennal cleaner of ants in pursuit of deducing phylogenetic relationships (Schonitzer *et al.,* 1996). Studies aimed to trace the antennal cleaner architecture in relation to the ants lifestyles have not been carried out yet. The present study is an attempt in this direction where we explored the structural details of the antennal cleaner in these ants to ascertain the differences.

MATERIALS AND METHODS

D. rugosum, *M. barbarus*, *M. brunnea* and *O. smaragdina* ant species were selected for the studies. Ant species for the present study were collected using polythene bags and insect collection aspirators from different localities in and around Changanassery, Kerala and brought to the laboratory and cold anaesthetized by keeping it in the refrigerator for 24 hours. Legs were dissected out from the anaesthetised specimens and immediately fixed in 4% paraformaldehyde. Leg preparations were dehydrated in graded ethanol series of 30-100% ethanol for sixty minutes in each step. The dehydrated specimens were finally cleared in methyl salicylate. After drying the specimens at a critical point, the specimens were mounted on the stub using a double side adhesive tape. The preparations were gold sputtered and dried in the desiccator. Samples were scanned under 15k Vemission current and desired images of various magnifications were captured by SEM JEOL JSM 6390.

Statistical analysis: One way ANOVA and Kruskal –Wallis tests were conducted to assess the significant differences in the morphometric features of the ants selected for the study

RESULTS

The tarsal notch and the tibial spur are the prominent features of the antenna cleaner of ants. Further the notch and spur bears common features like comb, brush, bristles (setae) and spines, which all together make up the composite structure of the antennal cleaner.

Antennal cleaners of the ants show structural similarities in general, but the subtle and significant differences are noteworthy. The tarsal notch is most prominent in *O. smaragdina;* the concavity of the tarsal notch runs deep and is richly endowed with the paddle or oar shaped brushes (setae), which are distributed along the entire concavity of the tarsal notch. The paddle shaped brushes are clubbed and densely distributed in comparison to the other ants considered for the present study. Comb of tarsal notch of *O. smaragdina* has a significantly higher number of brushes (setae) by virtue of their closely arranged packing (Table 1). Tibial spur has a length of 300 μm. There were more than 100 comb tines on the tibial spur, which accounts for the highest number in the case of the ants in the present study. Individual length of the tine is approximately 30 μm, It was observed that the setae of tarsal notch of the ants have a unique pattern of distribution

Table 1. Morphometrical features of the antennal cleaners of ant species

Ant species	Tibial spur comb length (µm)	Tarsal notch comb length (µm)	Tarsal spur and tibial notch comb tine length (µm)	Tarsal notch (brush) (Total number)	Tibial notch Spines
Oecophylla smaragdina	300 ± 12µm[b]	300 ± 6µm[a] 110 ± 8.6[a]	30 ± 4.6µm[a]	32 ± 8.4µm[a] Dense distribution along the entire concavity of the tarsal notch (Tip of the Setae of the comb tapers and ends in a pointed tip).	-
Myrmicaria brunnea	200 ± 8µm[a]	300 ± 8µm[a]	60 ± 6.2µm[b]	56 ± 6[b] Distribution partially and scarcely along the tarsal notch.	-
Messor barbarus	200 ± 9.4µm[a]	150 ± 6µm[b]	30 ± 3.4 µm[a] 25 ± 4.6 µm	52 ± 4.8[b] Sparse distribution along the concavity of the tibial notch (Oar like appearance of the setae with the terminal portion flat).	-
Diacamma rugosum	350 ± 6.8µm[c]	300 ± 9.6µm[a]	50 ± 6,6[c d] 80 ± 11.4	60 ± 4c Dense distribution along the entire concavity of the tarsal notch. longest ones with approximately 125 µm in length.	Stout and long spines on the outer margin of the tarsal notch.

Mean with the same letter are not statistically significant; All values are mean ± SD, n=10;
*Indicates significant differnces from each other: PÂ0.01, n=10

compared to other ants (Fig. 2a-b).The subterranean ant *M. brunnea* also has similar morphometric features, however its tarsal notch has two types of tines; the distal ones are oar shaped and comprises 10-15 in number, and the rest of the tines are of similar length but has bluntly ending tips (Fig.1a-b). *M. barbarus* has a significantly lower length of the comb tine on the tarsal spur and tibial notch respectively (Fig. 2c-d). The total length of the comb is also significantly less. The distal tarsal tines appear as oar shaped and the rest of the comb tines end bluntly and have relatively similar number of combtines all together on the tarsal and tibia combs. *D. rugosum* has the most contrasting antennal cleaner among the studied ants. The tines of the tarsal notch have 50µm length whereas the tibial spur tines are approximately 110µm. The tibial notch is conspicuously endowed with an unique array of long and prominent spines (Fig.1a-b) The finger like projections of the inner tibial notch (brush) is densely distributed and has a similar appearance to that of *O. smaragdina.*

DISCUSSION

Ants selected for the present study are considered as good foragers (Plowesand Holldobler, 2013). They forage on different substrata and are likely to encounter dust, mud, clay, bacteria, virus, pollen, fungal spores, salt or other particulate matters on the antennal surface in different levels by their for aging preferences and feeding habits.The differences revealed in the organisation of the antennal cleaner of the ants, throws some light into different antennal grooming methods adopted by the ants. *O. smaragdina* is arboreal, group forager and carnivorous. They also are found to be mutually associated with mealy bugs and other homopterous like aphids to devour honey dew those organisms produce. Previous studies indicated that brushes present on the tarsal notch help in adhesion of particles of size less than 5µm (Hackmann *et al.,* 2015), suggesting that the dense distribution of brushes on the tarsal notch of *O. smaragdina* points towards a heavy reliance on adhesion

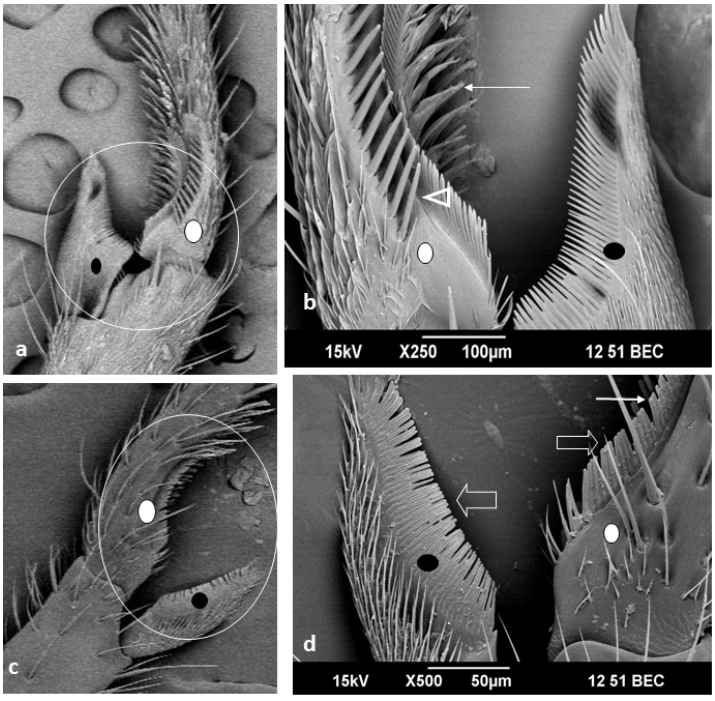

Fig. 1a. SEM microphotograph of the antennal cleaner of *Diacamma rugosum;* **1b**. Enlarged view of the antennal cleaner. the black dot corresponds to the tibial comb;white dot corresponds to tarsal comb. Tail less arrow point to the stout spines of *Diacamma,*the thin white arrow corresponds to the paddle like bristles of the tarsal comb; **1c**.SEM microphotograph of the antennal cleaner of *Messor barbarus*; **1d**. White short arrows corresponds to the tarsal and tibial comb respectively, thin arrow corresponds to paddle shaped bristles

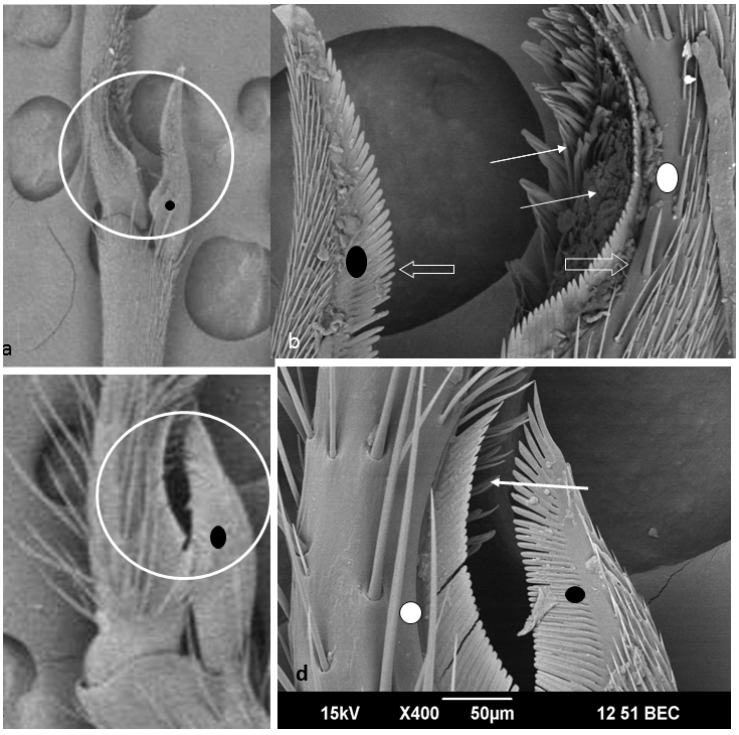

Fig. 2a.SEM microphotograph of the antennal cleaner of *Oecophylla smargdina*. Thin white arrows corresponds to the mat like structure and the paddle like bristles on the tarsal comb; **2b**.Thin white arrow corresponds to the paddle like bristles of the tarsal comb of *Myrmicaria brunnea*

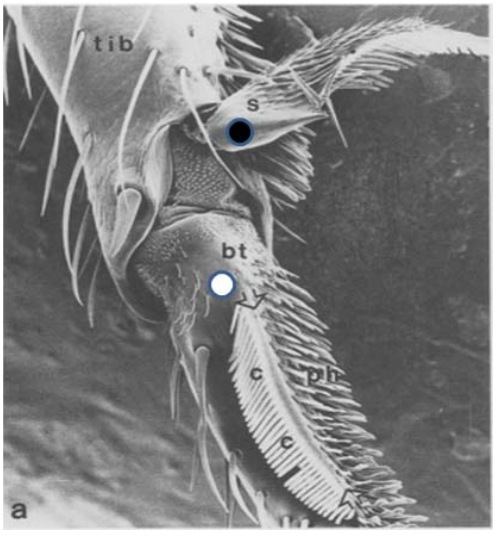

Fig. 3a. SEM microphotographof the antennal cleaner of *Messor rufitarsis*

mechanism of particles less than 5µm (Fig.1a-b). Further the highest number of the tarsal notch setae also suggests a heavy mode of scraping mechanism involved in their antennal grooming behaviour. However, it is difficult to draw definite conclusions, as conclusive evidences are required to ascertain whether the brushes of the tarsal notches are the main components involved in grooming demands associated with similar life styles. Antennal sensilla profile of *O. smaragdina* shows the presence of many unique sensilla like the thermo receptive ampullaceum and CO_2 receptive sensilla coeloconicum,which probably needs an intense cleaning because they are located below the antennal surface and opens through the antennal exterior through characteristic pores which are visible on the antennal surface. Clogging of such sensory pores through the detrimental particles can certainly interfere with the sensory perception. We speculate that the dense distribution of the brushes and the spongy mat like structures on the tarsal notches of *O. smaragdina* could certainly be helpful in such ways of antennal grooming

M. brunnea is a ground forager and lives in subterranean nests. It is considered a food opportunist and has a broad food spectrum. Though their tibial spur and tarsal notch bear morphometrical features similar to *O. smaragdina*, the tines of the combs are reduced significantly albeit with an increased length of the comb. The dichotomous pattern of the comb make up with oar shaped setae placed in the distal end is not so closely placed pattern compared to the tapering ended setae which constitutes the rest of the comb setae suggest the possibility more of scraping and the presence of very few paddle like brushes on the ventral side of the tarsal notch a comparatively less mode of adhesion mode of grooming in this ant. *M. barbarus* is the common harvester ants found in the grasslands and semi-arid areas, they are group foragers on the ground surface. In the present studies a significant difference in the total comb length of the tibial spur and the tarsal notch with a subsequent reduction in the length of the respective length of the comb setae, was noticed and noted that *M. barbarus* bears a miniature antennal cleaner among the ants in the present study. How ever compared results based on the study on the antennal cleaner of the European Harvester ant adapted to the temperate habitats of the Mediterranean areas - *Messor rufitarsis* (Schonitzer *et al*., 1996), showed a highly contrasting architecture of the antennal cleaner with the presence of densely present paddle shaped brushes on the tarsal notch meant for the purpose of adhesion; setae on the comb are distributed in a more spaced manner and they have blunt ends. *M.*

barbarus ants have brushes on the tarsal notch scarcely, which suggest of a relatively less dependence on adhesion mechanisms. It is obvious that *M. rufitarsis* (Fig. 3a) relies more on adhesion and scraping mechanisms than *M. barbarus.*

D. rugosum the largest of the ants in the study did not show a corresponding allometrical growth of the antennal cleaner, but the many features of the antennal cleaner is contrasting from that of the other ants taken in the study. The morphometric features of the combs of the tibial spur and the tarsal notches are similar to that observed in other ants in the study. How ever, the setae of the tibial spur have the highest length with pointed and slender ends and uniformly distributed throughout the tarsal notch. In addition, the presence of widely spaced thick spines which line the tarsal notch is also a significant feature of the antennal cleaner of *D. rugosum* (Fig. 3a). As spines are the reliable structures meant for the purpose of scraping, the study results point to a heavy mode of scraping in the ant, and a heavy distribution of the paddle shaped brushes densely distributed along the tarsal notch endorses the dependence on grooming mechanisms of adhesion in this antalso. Antennal cleaner of ants are the most elaborate ones in their architecture and represents complexities in their functional mechanisms (Basibuyuk and Quicke, 1994). However what appear more intriguing is the variations within the group. Though the general structure of the antennal cleaner is retained in these ants, significant deviations are evident from the statistical analysis. *M. brunnea* and *M. barbarus* though belong to the *Myrmicinae* subfamily are clearly distinct with their granivorous and carnivorous lifestyles and associated behaviours. *M. barbarus* possess a miniature antennal cleaner which is modest in its morphometric measurements in comparison to other ants. Contrastingly, the European harvester ants adapted to the temperate habitats and probably based on the resource availability possess contrasting antennal cleaner architecture Schonitzer *et al.* (1996).

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(Received 28 July 2018; revised ms accepted 21 September 2018; published 28 September 2018)

ENTOMON 43(3): 171-176 (2018)
Article No. ent. 43304

Parasitism potential of *Campoletis chlorideae* Uchida (Hymenoptera : Ichneumonidae) against *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae)

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ABSTRACT: Studies were conducted on nutritional requirement and host age, specificity and density that play a vital role in mass rearing of the parasitoid *Campoletis chlorideae* Uchida a solitary larval parasitoid of *Helicoverpa armigera* (Hubner), a notorious and polyphagus pest of pulses and vegetables in India. Results indicated that *C. chlorideae* fed with 50% honey solution was best suited for maximum longevity of adults. *H. armigera* was the most suitable host and exposure of 3-6 day old caterpillars at a density of 20 gave maximum progeny production that can be effectively utilized in mass rearing programmes for field release.

KEY WORDS: *Campoletis chlorideae*, mass rearing, biocontrol, *Helicoverpa armigera*

INTRODUCTION

Helicoverpa armigera (Hubner) (Noctuidae: Lepidoptera) is a polyphagus and notorious pest of pulse crops in India (Bhosale, 2014). Among the biocontrol agents recorded on the pest *Campoletis chlorideae* Uchida (Hymenoptera : Ichneumonidae) is the most common and potent solitary larval parasitoid that can control the pest population effectively (Pawar *et al.*, 1989; Romeis and Shanower, 1996). Host searching and host density and high rate of parasitism are important factors for the success of biocontrol programme of any pest species (Sathe and Bhosale, 2012). In mass production of parasitoids nutritional suitability and age of host play an important role (Vinson, 1976; Vinson and Iwantsch, 1980).

Leong and Oatman (1968), Lingren and Nobel (1972), Eliopoulos (2007), Sathe and Bhosale (2011) and Khatri *et al.* (2012) made investigations on optimum age, density and specificity of hosts and nutritional requirement of ichneumon parasitoids. Several workers contributed on parasitism potential of *C. chlorideae* (Gupta *et al.,* 2004; Dhillon and Sharma, 2011; Ballal *et al.,* 2015 and Dubey *et al.,* 2017). The present study was carried out with *C. chlorideae*, a larval parasitoid of *H. armigera* to find out the optimum age of host, specificity and density for obtaining maximum progeny of parasitoids, which will help in mass rearing and field release for an effective biocontrol program against the pest.

MATERIALS AND METHODS

H. armigera were reared individually in small perforated plastic containers (7x8 cm, D x H). After adult emergence they were transferred to oviposition cages (25x25x25 cm, LxWxH). First

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instar caterpillars that usually hatch two days after oviposition. They were collected and used for further experiments. During the course of study, the host caterpillars were fed with gram leaves initially and pods later. Similarly, the hosts used to conduct the host specificity experiment were reared on their natural food like, *Spodoptera litura* (Fabricius) and *Achaea janata* (Linnaeus) on leaves of castor *Ricinus communis* L. and *Mythimna separata* Walker on leaves of maize *Zea mays* L.

Adults of *C. chlorideae* were reared in ventilated wooden cages (30x30x30 cm, LxWxH) with glass walls on three sides and top while one wall was made up of very fine mesh cloth for handling of parasitoids. The adults were fed with 50% honey solution. Adults of parasitoids that were released for oviposition in the rearing cages with different age and densities of *H. armigera* caterpillars. After 24 h, adults were removed and the cocoons of parasitoids then transferred into separate containers and adults of *C. chlorideae* that emerged out were used for experimental purpose. Emerged adults of *C. chlorideae* were fed with different food materials like 100% honey, 50% honey, 10% honey, 50% sucrose, 50% glucose, apple fruit juice, citrus fruit juice and water solution to analyze the ideal feed for getting highest longevity and nutritional requirements.

Host age related parasitism:

To determine the effect of host age on parasitism, 20 larvae of *H. armigera* of known age (ranging from less than 1 day to 13 days old) were exposed to single mated female of *C. chlorideae* in a glass cage for 24 hrs. The larvae were removed and placed in separate containers for further observations. Daily records of cocoon construction and parasitoid emergence from each container were observed.

Host density for optimum parasitization:

H. armigera caterpillars (4-5 day old) were exposed in densities of 10, 20, 30, and 40 towards mated females of *C. chlorideae* for 24 hrs in oviposition cage. Each experiment was replicated five times to confirming results. The host larvae were reared into plastic containers to record further development or parasitoid emergence.

Host specificity for optimum parasitization:

Host specificity was conducted by exposing the mated females of parasitoid towards caterpillars of different host species like *H. armigera*, *S. litura*, *M. separata* and *A. janata*. The hosts were placed in the oviposition cage for 24 h. Hosts were released in 20 densities for each replicate with multiple choice test experiment to record optimum parasitism. Afterwards the hosts were reared on the natural diet and observe the emergence of parasitoid or further lifecycle of host species.

The field experiments were carried out for western Maharashtra region and the *in-vitro* condition of 25±2°C, 60±5% RH and 12hr. photoperiod. During the course of the experiment (2015-16, 2016-17), gram pods were provided as a food to the caterpillars of *H. armigera* and other appropriate food for other experimented host species, while the parasitoids were fed with 50% honey solution. Each experiment was repeated five times for confirming the result. The statistical analysis was made by one way ANOVA Tukey's standardized range (HSD) test using the statistical software package SAS 9.3(32) English.

RESULTS AND DISCUSSION

Host specificity experiment revealed that the parasitoid preferred *H. armigera* as the primary host with 40% parasitism. Among tested hosts, the parasitoid showed 19 per cent parasitism for *S. litura*, 15 per cent parasitism for *M. separata* and 6 percent parasitism for *A. janata* (Fig.1). Adult longevity of *C. chlorideae* with different food materials indicated that the parasitoid survived longer with 50% honey solution with maximum male: female longevity ratio (1: 1.39) (Fig. 2). The maximum longevity of male and female when fed with 50% honey solution was 8.2 and 11.4 days respectively. Hence, it could be best suited for mass rearing of parasitoid in the laboratory. The

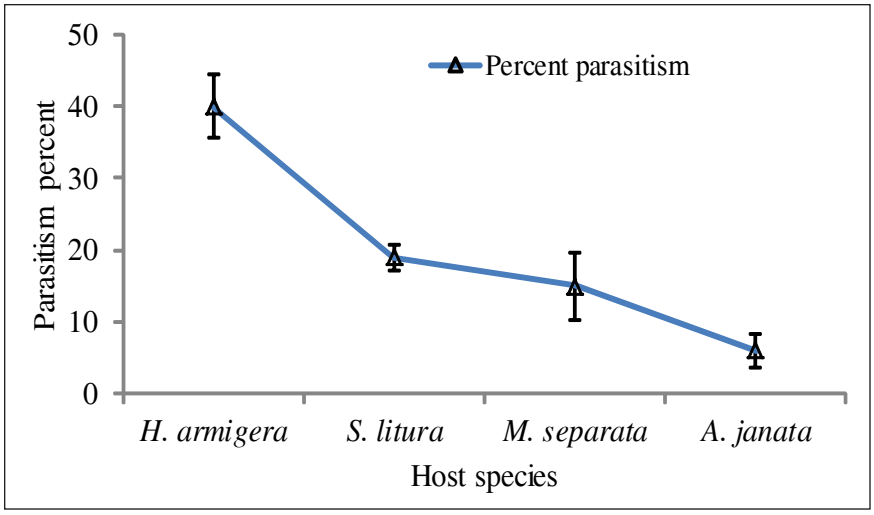

Fig. 1 Host specificity of *C. chlorideae*

*Each value is the mean of five replicates with error bars indicating standard error of mean

parasitoid caused maximum mortality in second instar caterpillars (Table 1). The caterpillars of 3-6 days old were preferred for parasitism whereas, beyond 11 days old were not attacked by the parasitoid. Four day old caterpillars were attacked most with high percent parasitism (42%) which was on par with five day old caterpillars with 26 per cent parasitism.

The results of optimum host density for maximum progeny production of parasitoid showed that the number of parasitoids obtained from host density 20 was highest with 40.00 per cent parasitism, compared to those produced from other host densities 10, 30, 40 and 50 with 16.00, 32.67, 30.00 and 24.80 mean percentage parasitism, respectively. Pawar *et al.* (1989) studied the parasitism of *C. chlorideae* on *H. armigera*, and found that first to third instar larvae, are only parasitised; the percentage parasitism on other crops was 44·2 on sorghum, 33·1 on chickpea, 32·6 on pearl millet, 7·1 on groundnut and 4·2 on pigeon pea. Lingren *et al.* (1970) reported the host age preference of *C. chlorideae* towards four lepidopterous host species *Prodenia ridinia* (Craner), *P. praefica* Grote, *Trichopulsia ni* (Hubner) and *Pseudoletia unipuncta* (Hawarth). They reported that 1-8 day old caterpillars of all hosts were susceptible for parasitism, and 2-6 day old caterpillars were most acceptable. In present findings 2-9 day old caterpillars of *H. armigera* were susceptible, and 3-6 day old being most suitable for parasitism.

Nikam and Basarkar (1981) studied the reproductive potential of *C. chlorideae* and reported maximum parasitization at host density 40. Sathe and Bhosale (2011) reported a host density 100 for obtaining maximum progeny production (38.50%) of the ichneumonid parasitoid *Diadegma insulare* (Cameron). In *Campoplex haywardi* Blanchard, an ichneumonid parasitoid of *Pthorimoea operculella* Zeller, the optimum host density was 75 larvae per tuber for maximum progeny production (Leong and Oatman, 1968). In present findings a host density of 20 showed maximum parasitism (40%).

Han *et al.* (2013) studied the host preference and suitability in *C. chlorideae* and recorded the parasitism against hosts *H. armigera*, *M. separata* and *Spodoptera exigua* (Hubner). They found that the parasitoid showed maximum parasitism on *H. armigera* followed by *M. separata* and *S. exigua*. Dhillon and Sharma (2007), recorded survival and development of *C. chlorideae* on various insect and crop hosts and found maximum cocoon formation (82.4%) and

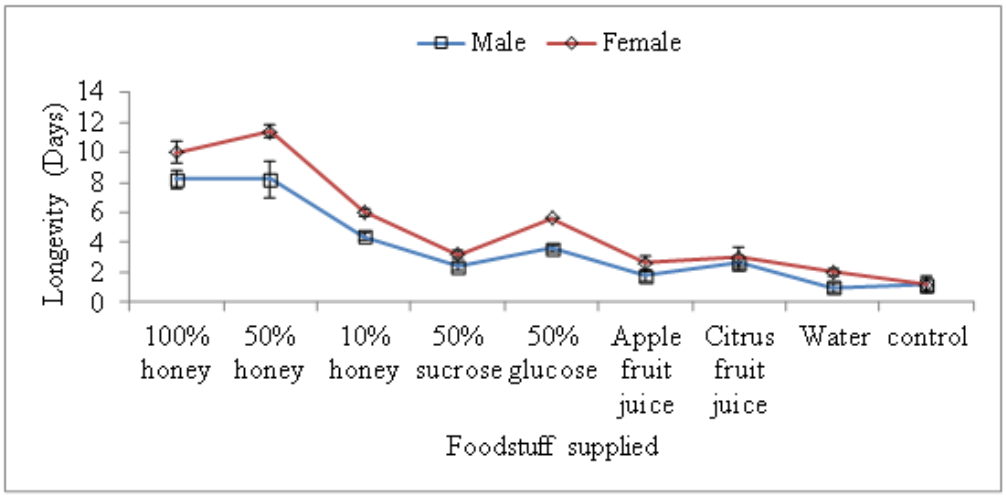

Fig. 2 Adult longevity of *C. chlorideae* with different food materials

*Each value is the mean of five replicates with error bars indicating standard error of mean

Table 1 Host age related parasitism by *C. chlorideae*

Host age (days)	% Parasitism	% Mortality	% Moth emergence
1	5.00 (±2.20)^{ef}	7.00 (±3.70)^{a}	88.00 (±2.50)^{ab}
2	9.00 (±3.70)^{de}	8.00 (±1.20)^{a}	83.00 (±3.70)^{abcd}
3	23.00 (±3.70)^{abc}	9.00 (±1.00)^{a}	68.00 (±3.00)^{de}
4	42.00 (±2.50)^{a}	9.00 (±2.90)^{a}	49.00 (±1.90)^{e}
5	26.00 (±3.70)^{ab}	7.00 (±2.50)^{a}	67.00 (±4.60)^{de}
6	22.00 (±3.40)^{abcd}	8.00 (±1.20)^{a}	70.00 (±2.70)^{cde}
7	15.00 (±0.00)^{bcd}	13.00 (±5.10)^{a}	72.00 (±5.10)^{bcd}
8	9.00 (±1.90)^{cde}	7.00 (±3.40)^{a}	84.00 (±1.90)^{abcd}
9	9.00 (±1.90)^{cde}	9.00 (±3.30)^{a}	82.00 (±4.60)^{abcd}
10	2.00 (±1.20)^{ef}	9.00 (±3.30)^{a}	89.00 (±2.40)^{a}
11	3.00 (±2.00)^{ef}	10.00 (±2.70)^{a}	87.00 (±2.50)^{abc}
12	0.00 (±0.00)^{f}	9.00 (±4.00)^{a}	91.00 (±4.00)^{a}
13	0.00 (±0.00)^{f}	12.00 (±3.40)^{a}	88.00 (±3.40)^{ab}
CD (P=0.05)	12.88	18.12	12.75

*The data presented are the mean of five replicates. Different letters indicate the significant difference (One way ANOVA) P<0.05 Tukey's standardized range (HSD) test. Figures in parentheses are standard error of mean (SEM).

adult emergence (70.5%) on *H. armigera* followed by *M. separata*, *S. exigua* and *A. janata*. In present findings the preference of the parasitoid to various hosts was in the order *H. armigera* >*S. litura*>*M. separata*>*A. janata*. To conclude the parasitoid *C. chlorideae* can be mass reared in the laboratory by using 50% honey solution as adult food and for getting maximum progeny of the parasitoid 3-6 day old *H. armigera* caterpillars may be exposed with a host density of 20 caterpillars.

Table 2 Host density dependent parasitism by *C. chlorideae*

Host density	% Parasitism	% Mortality	% Moth emergence
10	16.00 (±1.61)[b]	20.00 (±0.24)[a]	64.00 (±1.61)[a]
20	40.00 (±1.12)[a]	17.00 (±1.47)[a]	43.00 (±2.38)[b]
30	32.67 (±0.84)[a]	16.33 (±0.61)[a]	51.00 (±1.14)[ab]
40	30.00 (±0.87)[ab]	15.50 (±0.30)[a]	54.50 (±1.16)[ab]
50	24.80 (±0.43)[ab]	15.60 (±0.37)[a]	59.60 (±0.64)[ab]
CD (P=0.05)	12.58	8.08	11.99

*The data presented are the mean of five replicates. Different letters indicate the significant difference (One way ANOVA) P<0.05 Tukey's standardized range (HSD) test. Figures in parentheses are standard error of mean (SEM).

ACKNOWLEDGEMENTS

Author is thankful to the Coordinator, Department of Agrochemicals and Pest Management, Shivaji University, Kolhapur, Maharashtra for providing necessary facilities and Golden Jubilee Research Fellowship, Shivaji University, Kolhapur, Maharashtra for providing financial assistance to the research project.

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(Received 22 July 2018; revised ms accepted 22 September 2018; published 10 October 2018)

Entomon 43(3): 177-180 (2018)
Article No. ent. 43305

Redescription of female *Palaciosa khandalensis* Bolívar, 1930 (Orthoptera: Acrididae: Calliptaminae)

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ABSTRACT: Eightytwo years after its description, female specimens of *Palaciosa khandalensis* Bolívar, 1930 were discovered at a new locality. Opportunity is taken to redescribe and illustrate the female including its genitalia with its distribution.

KEY WORDS: Endemic, genitalic structures, taxonomy, redescription, Western Ghats, India

INTRODUCTION

The genus *Palaciosa* was established by Bolívar (1930) for the species *khandalensis* from Khandala in the Maharashtra state of India. The genus belongs to subfamily Calliptaminae Jacobson (1905) which includes 93 valid species in 12 genera globally (Cigliano *et al*. 2018). *Palaciosa* is a monotypic genus and endemic to Western Ghats of India, a globally accepted biodiversity hot spot (Myers, 2000). After Bolivar (1930), there are no published data reporting on new findings of this species. Therefore, till now this species is known from type locality only. No detailed study of the female genitalia has been carried out so far. Eightytwo years after the first description, fresh specimens of this species were collected. In the present paper, the female of this species is redescribed and illustrated along with its genitalic structures.

MATERIALS AND METHODS

The specimens were collected from Maharashtra state in India during a survey conducted out in connection with a major research project entitled "Diversity of Acridoidea (Orthoptera) in different parts of Western Ghats of India" in 2012. The specimens collected were processed following the method of Usmani (2009) and Kumar and Usmani (2015). Morphological measurements were done by using a vernier calipers. Figure 1A was taken by an Olympus SLR digital camera and figure 1B to 1M were obtained by a digital camera attached to a Nikon stereozoom microscope. Figure 2 to 5 were obtained by using a drawing tube attached to a Nikon stereozoom microscope. Scaling was done by using an ocular micrometer. The dissected female genitalic structures were kept in vials containing glycerine and pinned under the specimens. The terminology used for external

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morphology follows Uvarov (1966) and for female genitalia Slifer (1939) and Agarwala (1952). Identification was done with help of the description given by Bolivar (1930). All the specimens are deposited in the Zoological Museum of the Aligarh Muslim University, Aligarh, India (ZDAMU).

RESULTS AND DISCUSSION

Genus *Palaciosa* Bolívar, 1930

Palaciosa Bolivar, 1930, Eos, 6: 375 (Type species: *Palaciosa khandalensis* Bolívar, 1930); Jago, 1967: 401; Otte, 1995: 158; Yin, Shi and Yin, 1996: 494; Shishodia, Chandra and Gupta, 2010: 25.

Diagnosis: Body of medium size; integument finely dotted; antennae long and filiform; fastigium of vertex obtusely rounded; frons reclined and smooth but slightly punctate; frontal ridge broad and flat; pronotum weakly tectiform, dorsum crossed by three transverse sulci, median and lateral carinae distinct, lateral carinae diverging towards posterior end of pronotum, although their maximum separation is found in the mesozona; metazona longer than prozona, posterior margin rounded with a median incision; prosternal process wide and transverse; mesosternal interspace open; tegmina lateral, scale-like with rounded apex; hind femur short and moderately robust; arolium of medium size.

Palaciosa khandalensis Bolívar, 1930

Palaciosa khandalensis Bolívar, 1930. *Eos*, 6: 378 (holotype - male; India: Maharashtra, Bombay, Khandala; deposited in MNCN Madrid, Spain); Otte, 1995: 158; Shishodia, Chandra and Gupta, 2010: 25.

Redescription (Female): Body (Fig. 1A) robust and slightly compressed. Antennae (Fig. 1E) 24 segmented, as long as or slightly shorter than head and pronotum together. Head (Fig. 1F) obtusely rounded, shorter than pronotum. Eyes oval in shape, maximum diameter of eye longer than the interocular distance.Fastigium of vertex (Fig. 1B) declining, wider than long, shorter than eye length, flat with slight depression, lateral carinae obtuse, median carinula absent, apex obtusely rounded. Vertex convex without any carinula; width of vertex between the eyes much wider than the frontal ridge between the antennal sockets.Fastigial foveolae absent. Frontal ridge (Fig. 1C), in side view, slightly convex; margins diverging below the middle ocellus, never reaching up to the clypeus. Pronotum (Fig. 1B) longer than wide, lateral carinae parallel in prozona, separated backwards in mesozona and again parallel in metazona, prozonaless punctate than metazona, posteroventral angle obtusely rounded. Prosternal process (Fig. 1H) with roundly truncated apex. Mesosternal lobes (Fig. 1D) rounded and mesosternal interspace wider than long, margins rounded; metasternal lobes almost contiguous. Tegmina (Fig. 1G) reaching to middle of 1st abdominal segment. Hind femur with upper carina serrated while lower carina smooth, slightly reaching to tip of abdomen, lower apical lobe (Fig. 1I) rounded. Hind tibia cylindrical, shorter than hind femur; hind femora with 8 outer and 9 inner spines; inner pair of spurs longer than external spurs (Fig. 1J).

Genitalia: Supra-anal plate (Fig. 1K, Plate 1) broadly angular, as long as wide, basal dorsal half with narrow median longitudinal groove, apex obtusely conical; cerci short and conical, slightly longer than wide with obtuse apex. Subgenital plate (Fig.1L, Plate 1-3) smooth and convex; posterior margin forming an acutely angled projection in the middle. Spermatheca (Fig. 4) with tubular apical and pre-apical diverticulum; pre-apical diverticulum long and narrow, longer than apical diverticulum, with slightly bulging apex. Ovipositor (Fig. 5) with dorsal valve broad with slightly serrated external edge, more than three times longer than wide, shorter than lateral apodeme, curved apically with blunt apex; ventral valve narrower than dorsal valve with apical tip curved and blunt; medial valve slightly dilated apically with truncated apex.

Materials examined: INDIA, Maharashtra, Nashik, Anjaneri, 19.93995N, 73.592749E, 3♀, 20-x-2012, on grasses (Coll. by H. Kumar).

Measurements (length in mm): Female: Body: 33.69; Pronotum: 7.15; Antenna: 11.60; Tegmina: lobiform; Hind Femur: 18.36.

Distribution: India: Maharashtra.

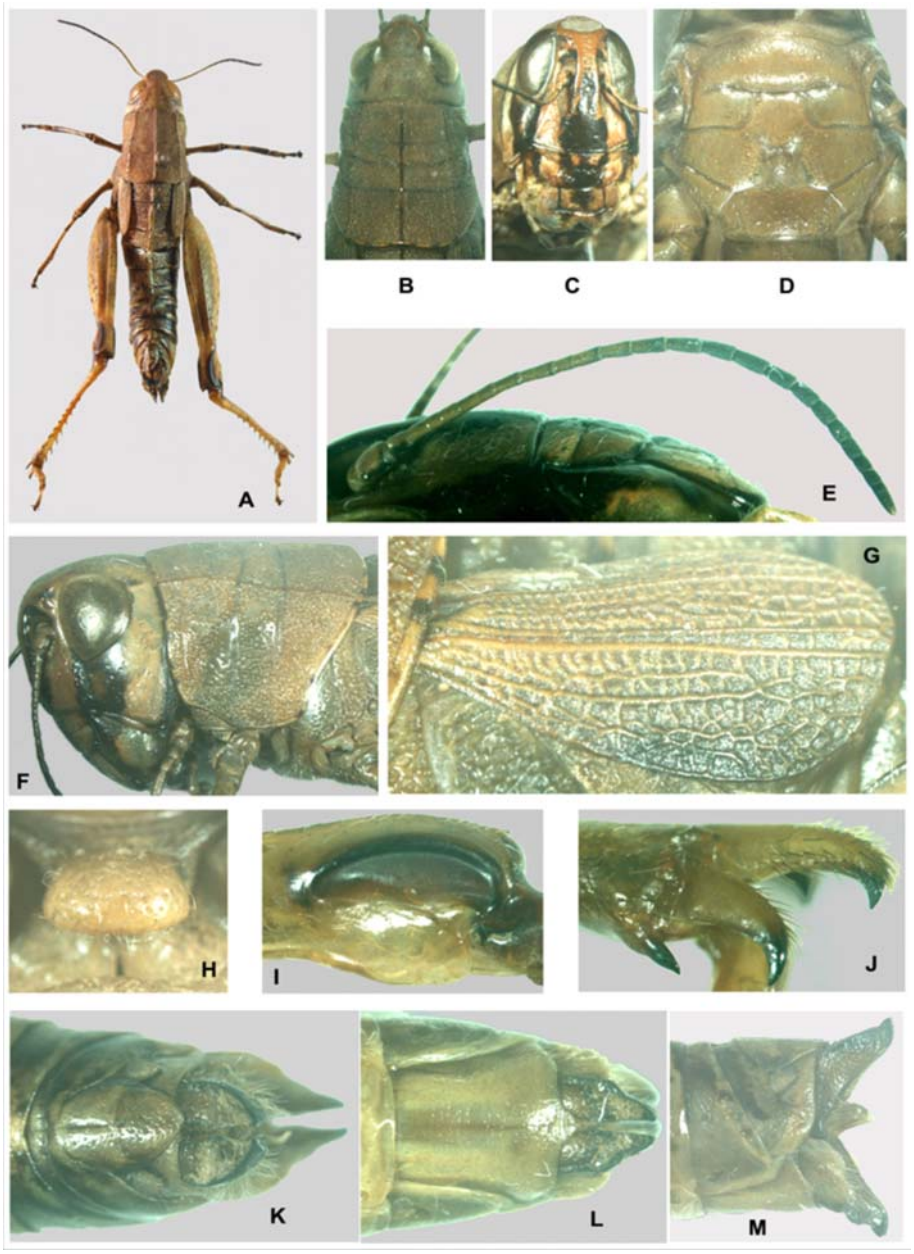

Fig.1 (A–M). ***Palaciosa khandalensis*** **Bolívar, female.** A– dorsal view; B–Dorsal view of head and pronotum; C–Frontal ridge; D–Ventral view of sternum; E–Antenna; F– lateral view of head & pronotum; G–tegmen; H–Prosternal process; I– hind knee; J– hind tibial spur; K– dorsal view of abdominal apex; H– ventral view of abdominal apex; I–lateral view of abdominal apex

ACKNOWLEDGMENTS

The authors are highly thankful to the Chairman, Department of Zoology, Aligarh Muslim University, Aligarh for providing the necessary facilities. We wish to extend our gratitude to the Ministry of the Environment Forest and Climate Change, New Delhi for providing financial assistance during the tenure of a major research project (Ref. No. 23/ 14/2010 – RE; Dt: 23.01. 2012) being carried out on "Diversity of Acridoidea (Orthoptera) in different parts of Western Ghats of India"

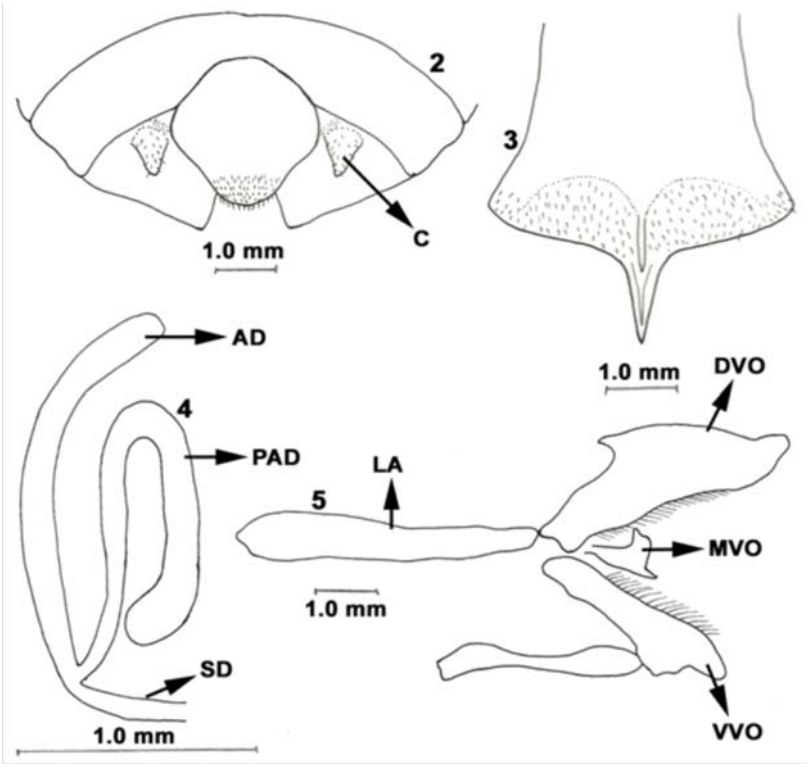

Plate 1 (2–5). ***Palaciosa khandalensis*** **Bolívar, female.**
2– supra-anal plate; 3–subgenital plate; 4–spermatheca; 5– ovipositor.

Abbreviations: C– cercus; AD– apical diverticulum; PAD– pre-apical diverticulum; SD–spermathecal duct; LA– lateral apodeme; DVO– dorsal valve of ovipositor, MVO– median valve of ovipositor; VVO– ventral valve of ovipositor.

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(Received 04 June 2018; revised ms accepted 25 July 2018; published 10 October 2018)

ENTOMON 43(3): 181-188 (2018)
Article No. ent. 43306

Pests of mandarin orange and its importance in Sikkim, India

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ABSTRACT: Mandarin orange (*Citrus reticulata* Blanco) is a major cash crop in Sikkim and in this paper the pests of mandarin orange obtained through inputs from farmers of Sikkim are documented with symptoms of pest attack and prevalence of important pests. Citrus long horned beetle (*Anoplophora versteegi*) was the most destructive pest followed by stem borer Japanese beetle (*Popillia japonica*) and four Hemipterans (*Planococcus citri, Toxoptera aurantii, Toxoptera citricidas and Diaphorina citri*) collectively called *laikira*. These pests were common across all sites as compared to other pests. This work can serve as a baseline for future researchers as well as government agencies to engage in management of these pests.

KEYWORDS: Sikkim mandarin orange, pests, prevalence, infestation

INTRODUCTION

Sikkim is India's first organic state and more than 67% of the total population depend on agriculture for livelihood (Joshi, 2004). Out of 7096 sq km area of Sikkim, mandarin orange is cultivated in approximately 12380 hectares. Native orange is grown in all the four districts of Sikkim between 600 – 1500 meters above mean sea level. There has been a three-fold increase in area under orange (4250 to 12340 hectares) between 2001-2002 and 2015-2016. It contributes significantly to the rural economy as more than 12000 farming families are directly dependent on orange for their livelihood.

The importance of orange as a cash crop has amplified due to the drastic decline of large cardamom (*Amomum subulatum*) which was the most successful cash crop in Sikkim till 2000. The area under cultivation of large cardamom had increased by 2.3 times between 1980 and 2000. Since early 2000, the area under *Amomum subulatum* declined by almost 50% (Sharma and Dhakal, 2011). Large cardamom yield declined drastically in the last decade due to fungal diseases, pests and decline in its major pollinator *Bombus sp* (Savory *et al.*, 2014; Sharma *et al.*, 2016; Sinu and Shivanna, 2007).

Orange cultivation has also begun to see a decline in terms of acreage as well as productivity. The emergence of diseases such as citrus dieback, powdery mildew, root/foot rot, shoot mould, anthracnose, red rust, scab, *Tristeza* virus - vascular

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borne disease, colonization of ants in citrus plant have been reported in recent years in orange orchards across Sikkim (Sharma and Dhakal, 2011). Pests have been known to affect productivity of crops since the dawn of agriculture with farmers constantly looking for methods to protect their crops from various organisms (Oerke, 2006). Insect pests are major competitors with human for the fruits of agricultural production and the damage caused by them is a primary factor in the reduced productivity of crop species (David Pimental, 1976); Metcalf, 1996; Oerke, 2006). Early detection and control of pest species are extremely important if large outbreaks of major cash crops are to be avoided.

Lack of reliable information on major insect pests and their spread is a major stumbling block for containing insect pests in Sikkim. This assumes additional importance when the crop in question is critical to people's livelihoods (Sharma *et al.,* 2000; Subba, 2009). In this paper, a first-hand knowledge on prevalence of insect pests across the distributional range of orange in Sikkim was attempted.

MATERIALS AND METHODS

Study Area:

Sikkim, located in Eastern Himalayan region is a biodiversity hotspot with a geographical area of 7096 sq km area. Approximately 9% of the total geographical area is dominated by cultivated area which can be seen interspersed between human habitations and forest patches. They grow various crops like large cardamom (*Amomum subulatum*), mandarin orange, ginger, variety of vegetables, cereals and pulses. With slow or little hope of large cardamom rejuvenation, government started rejuvenating orange orchards, expanding its cultivation in the area. This study was conducted in mandarin orange orchards (Fig. 1) covering East, West and South districts of Sikkim. Semi-structured interviews were conducted with 81 orange growers in Southern Sikkim.

The respondents were chosen to accommodate orchards of different sizes from a larger group that comprised all orange farmers in these three districts. The interviews were conducted in the local language and recorded using a digital voice recorder with prior permission from the farmers or the responses were directly transcribed on to a note pad. Prior to this, two years were spent in the field conducting ecological research and building rapport with the locals. The first section of the questionnaire had questions typically on the farmer's household data and agricultural data with emphasis on pests of orange were recorded. Information on pests, symptoms on the plants after pest attacks and approximate time line of pest attack were recorded.

Farmers were requested to show us the pest attacks in their orchards. Since the entire range of pests were not available throughout the year, photographic evidence of the pest or affected part of the plant were taken (where possible). A preliminary list of pests was prepared after the interview and field visits, which was verified through secondary literature survey, communication with taxonomists and photographic identification of the pests by the farmers themselves.

RESULTS AND DISCUSSION

There were 13 different pest species affecting orange. They belonged to 12 families from four taxonomic orders namely Coleoptera, Diptera, Hemiptera and Lepidoptera (Table 1).

Sampled orchards were infested by more than one pest at any given time of the year. Farmer's input and field survey highlighted that these pests were found to attack different parts of orange such as leaves, trunk, branch, roots and fruits. All the pests reported in this study have been found to heavily impact *Citrus* production across the world (Cerda et al., 2017; Parsa et al., 2014; G. Sharma and Dhakal, 2011). However, their abundance and attack intensity varied across sites. The intensity of attack also varied in a given year. For example, most prevelent pest Japanese beetle (*P. japonica*) was highlighted. It was found throughout the year but its abundance and attack intensity was more in spring and monsoon. On the other hand citrus long-horned beetle (*A. versteegi*) emerged in March –

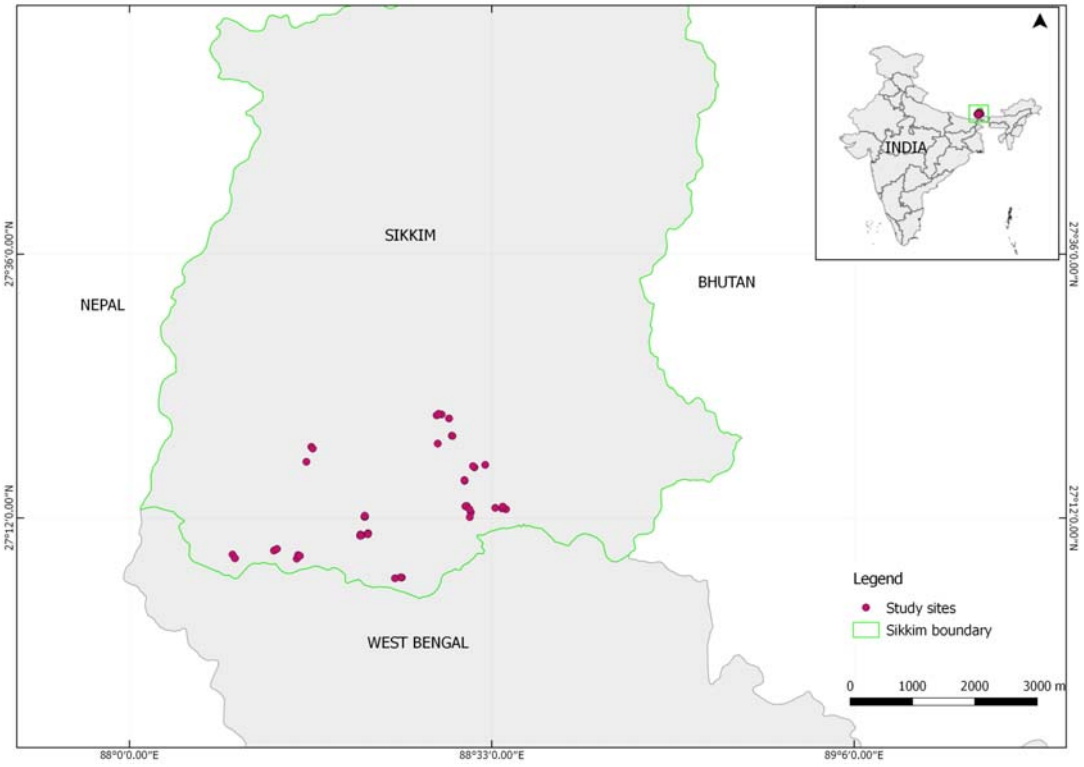

Fig. 1. Map shows location of Sikkim in India and study sites highlighted by dots

April but was most abundant in May – August. Increase in pest abundance and attach intensity is more during monsoon season which begins roughly by late May and last till September end. With no chemical input, organic farming has been proven to have a positive impact on biodiversity as well as human well-being (Holzschuh *et al.*, 2008). However, this transition to organic agriculture brings with it a different set of challenges that includes pest management (Zehnder *et al.*, 2007) which were reported by farmers in our field sites also. Ever since Sikkim adapted its 'organic mission', both the state agencies as well as farmers are exploring ways to deal with pests and diseases in organic ways. As highlighted by Gopi *et al.* (2016)), from table salt to cow urine, cow dung, kerosene and local plants like *Eupatorium, Artemisia vulgaris* mixed with cow urine is being used as sprays to combat pest and diseases. The state agencies are engaging farmers in trainings and workshops to deal with pests and diseases naturally.

With changing climate, the abundance and intensity of pest and disease attacks have been reported to increase globally (Rosenzweig *et al.*, 2001). Farmers in Sikkim also expressed the idea that pest abundance, diversity and attack intensity has increased due to climate change induced erratic weather patterns - prolonged dry period followed by torrential short bouts of rain. This definitely deserves scientific exploration and validation in the future. However, studies across the world mention that due to their invasive nature, many pests are known to have adapted well to a diversity of climatic zones affecting numerous agricultural as well as wild plants (Kirk and Terry, 2003; Sharov and Liebhold, 1998). Pests recorded in this study for example, fruit fly (*B. dorsalis*) is a widely distributed invasive species with its origin in tropical Asia that has now spread across the globe. It has also been reported as pest of *C. reticulata* (Chen and Ye, 2007; Hui, 2001). The highly destructive mealy bug (*Planococcus citri*) is easily dispersed by wind

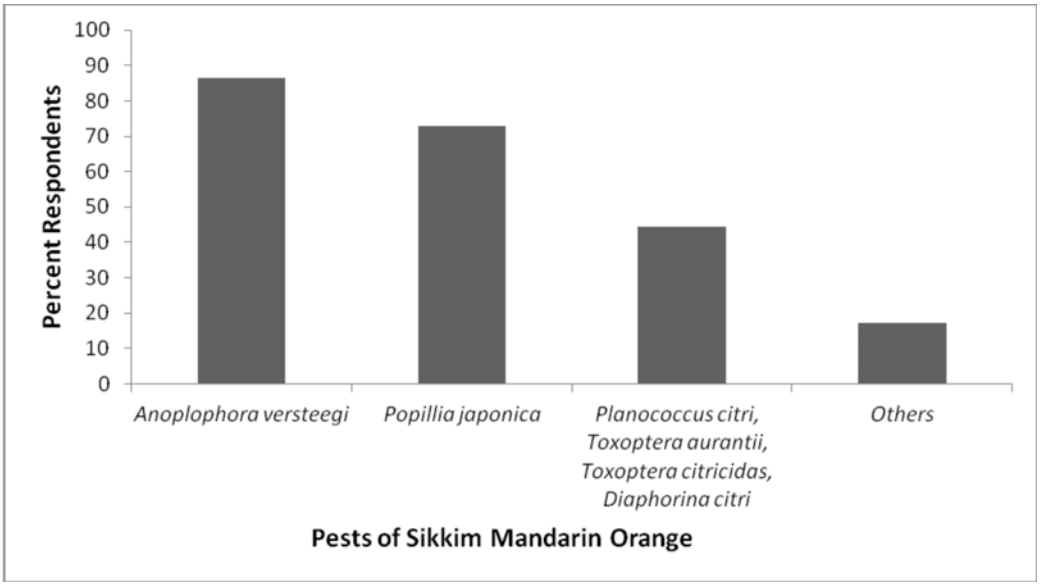

Fig. 2. Pest of orange ranked by farmers as most destructive to the crop

(Cornwell, 1960) making their spread across plants and even orchards easy. Integrated management of these pests requires an understanding of the diversity, abundance and intensity of pest attack after which control measures can be planned. The present study makes an effort to fill that gap by identifying the important pests of orange from the organically managed orchards of Sikkim.

All the pests listed from Sikkim are known to damage crops globally (Dedryver *et al.*, 2010; Mitchell, 1984; Pollard *et al.*, 1986) and will impact the economic benefit people derive from the cultivation of oranges. Farmers reported decrease in yield of oranges due to pest attacks, a research aspect which deserves more attention. Amongst the symptoms mentioned in the table, farmers highlighted yellowing of leaves and eventual death of plant as well as fruit fall caused by these pests as a major economic setback to them. As reported by Gu and Pomper (2006), attacks by Japanese beetle (*P. japonica*) and citrus long-horned beetle (*A. versteegi*) were cited as the main pests leading to crop loss by farmers. Based on interview results, we found that approximately 85% respondents reported citrus long horned beetle as the most destructive pest. This was followed by stem borer Japanese beetleas reported by 72% respondents and four Hemipterans (*P. citri, Toxoptera aurantii, Toxoptera citricidas and Diaphorina citri*) collectively called *laikira* by the farmers was reported to be destructive by 45% respondents. These pests were common across all sites as compared to others which were reported to be harming the crop by 18% respondents (Fig. 2).

Identification of the specific pest responsible for the damage was not always possible by the farmers because of similar and overlapping symptoms caused by different pests. Attempts were made to verify the identity of the pest through photographs and consultation with other experts but it was not possible to identify all the pests for all locations. An additional issue was that the farmer's usage of local terms for pests were generic in nature and not necessarily unique for each species. This highlights two important factors, one that some of these pests are considerably new to farmers or have increased in the recent past such as red scale (*Aonidiella aurantii*) and Japanese beetle. Secondly, having no knowledge about pests which is affecting their crop may also act as an obstacle in managing them later (Parsa *et al.*, 2014). The information generated by this work can be used as a baseline by other researchers to address distribution of the pest in the landscape and also investigate their

Table 1. Pests of Sikkim mandarin orange

Sl No	Scientific name	Local name	Common Name	Order	Family	Distribution	Symptom
1	*Popillia japonica*	*Padhera*	Japanese beetle	Coleoptera	Scarabaeidae	throughout the year, more abundant in spring and monsoon	Adult feed on foliage causing leaf skeletonization.
2	*Anoplophora versteegi*	*Singh kira*	Citrus long-horned beetle	Coleoptera	Cerambycidae	Emerges in March - April but is most abundant during May - August	Insects cause damage to leaves, roots, trunk and twigs. Feeding on leaves and petioles can result in yellowing or drooping of leaves. The major damage occurs in the roots, trunk and twigs by the larvae which burrow into the wood restricting water and nutrient transport and also secondary infection. Primary signs of infestation include round emergence holes, piles of sawdust and excreta and oozing sap
3	*Bactrocera dorsalis*	*Kanchi kira*	Fruit fly	Diptera	Tepthritidae	Primarily in summer	Attacks the fruit and the symptoms include black and brown lesions on the fruit, signs of internal feeding and premature fruitfall.
4	*Planococcus citri*	*Fusre lai kira*	Mealy bug	Hemiptera	Pseudo-coccidae	Spring and early summer	White cottony masses of eggs are deposited on trunks and stems of citrus plants. Wax and honeydey secreted by the insect nymphs are visible indicators of infestation. Infestation also leads to wilted distorted yellowed leaves, premature leaf drop, stunted growth and even death of infested plant parts or the entire plant in some cases. Fruit drop can result from mealybugs feeding near the buttonof oranges with oranges developing hard lumps and discoloured, poor quality fruit.
5	*Toxoptera aurantii*	*Kalo lai kira*	Black aphid	Hemiptera	Aphididae	Thrives at higher temperatures. Available throughout the year	Aphids sucking sap cause deformations on the plants causing curled and shriveled leaves and occasionally forming galls. Primarily attacks the tender young shoots, flower buds and the undersides of young leaves and avoid tougher plant tissues. Also secrete honeydew which can promote the growth of sooty fungus mould which can blacken the leaves, decreasing photosynthetic activity

Sl No	Scientific name	Local name	Common Name	Order	Family	Distribution	Symptom
6	*Diaphorina citri*	*Lai kira*	Citrus Psylla	Hemiptera	Psyllidae	March - April	The nymphs are completely exposed and can be seen with the naked eye. White waxy secretions on the leaves are symptomatic while they exhibit a variety of other symptoms on the leaves, stems, twigs and fruits. Leaves show yellowing, fruits are underdeveloped and hard with low juice with most of the seeds being small and dark coloured.
7	*Aonidiella aurantii*	*Rato thople papra*	Red scale	Hemiptera	Coccidae	Variable	The insect feeds on sap and are found on all parts of the plant but are more noticeable on the fruit. Leaf discoloration, shoot distortion and leaf drop are the common symptoms. The bark of the trees may split and even result in death of the tree.
8	*Bemisia tabaci*	*Seto kira putali jasto*	Whitefly	Hemiptera	Aleyrodidae	Thrives in higher temperatures but prevalent throughout the year	At first, the damage consists of yellowish spots. The leaves demonstrate a yellow mosaic, with the green areas turning smaller over time. Twisting of stems and curling of leaves may occur, and the plants may become stunted. Heavily-infested leaves often wilt and fall off. In addition to direct feeding, all stages damage the plants through abundant production of honeydew, which encourages the growth of sooty moulds, and, most importantly, by the transmission of viruses. The nymphs excrete large quantities of honeydew, which is rich in carbohydrates and supports the growth of sooty mold, causing parts of the plant to turn black
9	*Toxoptera citricidas*	*Seto lai kira*	Citrus/white aphids	Hemiptera	Aphididae	Throughout the year but thrives. Outbreaks occur after rains when new buds and leaves emerge	Leaves show chlorosis
10	*Papilio spp.*	*Chirke putali*	Citrus butterfly	Lepidoptera	Papilionidae	July - Dec	Caterpillars can completely defoliate young trees and in the case of mature trees, the young leaves are destroyed

Sl No	Scientific name	Local name	Common Name	Order	Family	Distribution	Symptom
11	*Inderbella quadrinotata*	*Kath khane larva*	Bark-eating caterpillar, bark borer	Lepidoptera	Cossidae	Throughout the year, more abundant in monsoon	Damage most visible on the bark with the damage caused by the larva boring into the trunk and branches creating tunnels underneath. Dark brown masses consisting of wood particles and faecal matter are seen plastered on the barks of infected plants
12	*Phyllocnistis citrella*	*Pat khane kira*	Citrus leaf miner	Lepidoptera	Gracillaridae	Whenever new leaves appear	Damage of leaves through leaf mining by larvae
13	*Eudocima sp*	*Seto moth*	Moth	Lepidoptera	Noctuidae	May - Dec	Damage to leaves near the shoot tips and areas where the leaf is rolled

impact on crop losses which directly impacts thousands of farmers of Sikkim. The information will also serve as an important outreach material to the concerned government agencies to sensitize farmers about the array of pests and to train them in identifying pests. Since orange orchards are pivotal to the sustenance of rural communities of Sikkim, the farmers may be trained to report the pest incidence and share local traditional management practices they use to counter pest out breaks that have disasterous effect on orange production.

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(Received 22 August 2018; revised ms accepted 24 September 2018; published 10 October 2018)

ENTOMON 43(3): 189-214 (2018)
Article No. ent. 43307

Distributional records of *Xanthopimpla* Saussure (Hymenoptera: Ichneumonidae: Pimplinae) from the southern Western Ghats with description of three new subspecies

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ABSTRACT: The distribution and diagnostic features of the species belonging to the genus *Xanthopimpla* Saussure from the southern Western Ghats are discussed. A total of 13 species groups are recorded, of which *Cuneata* species group is recorded for the first time from the region. Of the 34 species identified, six species are recorded as new to the study area, viz., *X. exigua*, *X. laticeps*, *X. verrucula, X. nigritarsis*, *X. sikkimensis* and *X. clivulus*, of which first three are new records to India. Three new subspecies are described with key. © 2018 Association for Advancement of Entomology

KEY WORDS: *Xanthopimpla*, diagnostic features, subspecies, Cuneata, Western Ghats, India

INTRODUCTION

The genus *Xanthopimpla* Saussure, first described by Saussure (1892) with *Xanthopimpa hova* as its type species, belongs to the tribe Ephialtini of subfamily Pimplinae. *Xanthopimpla* is one of the largest genuses of tribe Ephialtini, which include 261 species from the World, of which 165 species are described from Indo-Australian region (Townes and Chiu, 1970; Pham *et al.,* 2011). The genus is represented by 41 species with 12 subspecies from India, of which 28 species with 5 subspecies are reported from the southern Western Ghats (Akhtar *et al.,* 2010). In India, major works on *Xanthopimpla* have been published by Morley (1913), Cameron (1911), Townes and Chiu (1970), Townes and Gupta (1961), Patil *et al.* (1995), Akhtar *et al.* (2010), and Chougale (2016). One of the significant works on the fauna of *Xanthopimpla* was that of Townes and Chiu (1970) from Indo-Australian area. They categorized the genus into 20 species groups, of which 12 groups are known from southern Western Ghats. The genus *Xanthopimpla* can be easily identified by their stout, yellowish body with black spots or bands, clypeus divided by a median transverse suture and the narrow, pointed apex of mandible, which is twisted so that the lower tooth is directly behind the upper tooth. These parasitic wasps are important due to their abundance and their role as biological control

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agents, and the diversity in host records. The biogeographical data of species recorded from the southern Western Ghats is scattered. In this paper, an attempt is made to compile the distributional data with diagnostic features of all the species recorded.

MATERIALS AND METHODS

Specimens of the present study were collected using malaise trap and sweep net. Specimens were preserved in 70% alcohol. Pinned and dried specimens were observed under Magnus Stereozoom binocular microscope and were identified up to species and further to subspecies level, using the keys of Townes and Chiu (1970). Photographs were taken using Leica M80 microscope with Leica MC170 HD camera. Loaned specimens from Ashoka Trust for Research in Ecology and Environment (ATREE), Bengaluru were also included in this study. Specimens preserved in the collection of ICAR-NBAIR, Bangalore; University of Calicut; WGRC Kozhikode and NBRL, Kozhikode were also studied. Photographs of types, holotypes or paratypes of the species recorded from the study area but not represented in the present collection were obtained from International depositories in USA, Germany and Canada. Terminology used in this paper follows Townes (1969) and Wahl and Sharkey (1993).

Abbreviations used in the text are:

F = Female; M = Male; HW = Head Width; HL= Head Length; FWW = Fore wing width; FWL = Fore wing length; HWW = Hind wing width; HWL = Hind wing length; T2 - T8 = Metasomal tergites first to eighth; F1- F42 = Flagellomeres first to Forty two segments; ATREE - Ashoka Trust for Research in Ecology and Environment, Bengaluru

BMNH - British Museum of Natural History London

CNCI - Canadian National Collection of Insects, Ottawa

DEI - Senckenberg Deutsches Entomologisches Institut, Müncheberg, Germany

FDAC - Florida Department of Agriculture and Consumer Services, Gainesville, Florida

GBNH - Berlin Natural History Museum, Germany

GPTA - Delhi University, Department of Zoology, Gupta Collection, Delhi India

HMUG - Glasgow University, Hunterian Museum, Glasgow, United Kingdom

MZPW - Polish Academy of Science, Museum of the Institute of Zoology, Warsaw, Poland

NBAIR - National Bureau of Agriculture Insect Resources, Bengaluru, India

NBRL - Prof.T.C.Narendran (TCN) Biodiversity Research Laboratory, The Zamorin's Guruvayurappan College, Kozhikode

NHRS - Naturhistoriska riksmuseet, Stockholm, Sweden

OUMNH - University Museum of Natural History, Oxford, United Kingdom

RMNH - Netherland Centre for Biodiversity Naturalis, Leiden, Netherland

USNM - National Museum of Natural History, Washington D.C., USA

USU - Utah State University, Logan

UUZM - Uppsala University, Uppsala, Sweden

WGRC - Western Ghats Regional Centre, Zoological Survey of India, Kozhikode

ZMAN - Universiteit van Amsterdam, Instituut voor Taxonomische Zoologie, Zoologisch Museum, Amsterdam, Netherlands

ZMUC - University of Copenhagen, Zoological Museum, Copenhagen, Denmark

The holotypes of the new subspecies are deposited in Prof. T.C.Narendran Biodiversity Research Laboratory (NBRL) for the time being, which will later be transferred to WGRC, Zoological Survey India, Kozhikode.

RESULTS

The present study recognizes 13 species group under the genus *Xanthopimpla* from the southern Western Ghats with a total of 34 species and 18 subspecies, which includes 6 new records and

description of three new subspecies, viz., *X. elegans priyadarsanani* sub sp.nov., *X. elegans kadnurensis* subsp.nov. and *X. nigritarsis wayanadensis* subsp.nov. The thirteen species groups from the study are the Brachycentra, Citrina, Cuneata, Elegans, Incompleta, Nana, Occidentalis, Punctata, Regina, Stemmator, Terebatrix, Trunca, and Xystra. Among them Cuneata is recorded for the first from the southern Western Ghats. A key to the subspecies of *X. elegans* is also provided, with the description of the new subspecies. Six new records from the southern Western Ghats are, *X. laticeps, X. exigua, X. verrucula, X. sikkimensis, X. clivulus* and *X. nigritarsis* of which first three are new records to India. Distribution of *Xanthopimpla* sp. in the southern Western Ghats is shown in the map

BRACHYCENTRA SPECIES GROUP

Diagnosis: Mesoscutum with dense hairs between tegulae; largest bristles of mid and hind tarsal claws not widened apically; fore wing with areolet closed; ovipositor sheath 0.25 – 0.7x as long as hind tibia.

Xanthopimpla platyura Townes & Chiu, 1970

Xanthopimpla platyura Townes & Chiu, 1970. *Mem. Amer. Ent. Inst*. 14: 199. Holotype: ♀, Devala, Nilgiri Hills, south India (CNCI)

Diagnosis: Lateral flange of scutellum very high; areola 1.0 as long as wide; tergite3-5 with dense coarse punctures; ovipositor sheath 0.7 x as long as hind tibia.

Distribution: Previously recorded from Tamil Nadu (Townes & Chiu, 1970).

Material examined: Nil. Photographs of **Holotype**- 1♀, INDIA: Devala, Nilgiri Hills, x.1960, Nathan, CNCI examined.

Remarks: The diagnosis is based on the original description (Townes & Chiu, 1970) and the Photographs obtained from the CNCI, Ottawa.

Xanthopimpla reicherti reicherti Krieger, 1914

Xanthopimpla reicherti Krieger, 1914. *Arch. f. Naturgesch*., (A) 80 (6): 40, 89. Lectotype: ♀, Myanmar: Pekon on Loikaw River, Karenni State (GBNH).

Xanthopimpla reicherti reicherti Townes and Chiu, 1970. *Mem. Amer. Ent. Inst*. 14:187, ♂, ♀. Key, des., fig Type: ♀, China.

Diagnosis: Scutellum evenly convex; areola as long as wide; hind tibia with 5 - 6 preapical bristles; T1, T3, T7 each with black band; T4 & T5 each with two black spots; T2 nearly impunctate; T3 - T5 densely, coarsely punctate; ovipositor sheath 0.5x as long as hind tibia; mesoscutum with a transverse black band and a black spot infront of scutellum.

Distribution: Townes and Chiu (1970) previously recorded from the Karanataka region.

Material examined: Nil. Photographs of **Type**: 1♀, Tekoxloikaw R, GBNH; **Paratype**: 1♀, Tongking: Fruhstorfer.v, Townes, GBNH examined.

Remarks: The diagnosis is based on the original description (Krieger, 1914) and the photographs obtained from GBNH.

Xanthopimpla walshae walshae Townes & Chiu, 1970

Xanthopimpla walshae Townes & Chiu, 1970. *Mem. Amer. Ent. Inst*. 14: 199. Holotype:♀, Pelabuhan Ratu, Java (USU).

Diagnosis: Lateral flange of scutellum rather narrow, gradually narrower towards apex; carinae surrounding areola weak; T6 with a pair of black spots; middle and hind tibia with 3 to 5 preapical bristles; hind femur with a black stripe below and another near upper edge on hind side.

Distribution: Townes & Chiu (1970) previously recorded this species from Tamil Nadu.

Material examined: Nil**.** Photographs of **Holotype**: 1♀, INDONESIA: West Java, USU examined

Remarks: The species is not represented in the present collection and the diagnosis is based on the original description (Townes & Chiu, 1970) and Photographss obtained from the USU collection, Logan, USA.

CITRINA SPECIES GROUP

Diagnosis: Body and legs entirely yellow; except black ocellar area; clypeus weakly convex; lower front corner of the pronotum a broadly rounded

angle of about 110^0; mesoscutum with notaulus almost extending to anterior of tegula; scutellum evenly convex, lateral flange moderately high, reaching to apex; fore wing with areolet closed; largest bristles of mid and hind tarsal claws distinctly widened, black apically; areola closed, completely bounded by strong carina; ovipositor stout; ovipositor sheath about 0.65x as long as hind tibia.

***Xanthopimpla enderleini* Krieger, 1915**
(Plate 3, Fig. g, h)

Xanthopimpla enderleini Krieger, 1914. *Arch. f. Naturgesch*., (A) 80 (6): 35. Lectotype: ♀, Indonesia: Sumatra (MZPW).

Diagnosis: Stigma dark brown; areola receiving costula at the centre; areola 1.05 to 1.45x as long as wide.

Distribution: Townes & Chiu in 1970 recorded this species from Tamil Nadu

Material examined: 2♀, INDIA: Kerala, Kottayam, Kumarakom, (N9˚61′75″-E76˚43′00″), Santhosh S, 17.iv.2004.

***Xanthopimpla flavolineata* Cameron, 1907**
(Plate 1, Fig. f)

Xanthopimpla flavolineata Cameron, 1907b. *Tijdschr. V. Ent*. 50: 48, jk, keydes. Type: kdj, New Guinea: Merauke (ZMAN).

Xanthopimpla emaculata Szepligeti, 1908. *Notes Leyden Mus*, 29; 256. ♀. Key, des, Type: ♀, Java: semarang (Budapest). Syn, by Townes & Chiu, 1970.

Xanthopimpla immaculata Morley, 1913. *Fauna of British India....Hymenoptera*3(1): 115. ♂, ♀. Key, des. Type: ♀. India: Chapra in Bihar (New Delhi). Paratype seen in London. syn. under *emaculata* by Cushman, 1925

Xantopompla hyaloptila Krieger, 1914. *Arch. F. Naturgesch*. (A) 80 (6): 35. key; (A) 80 (7):16, ♂. des, fig. Type: ♂, Australia: North Queensland (Berlin). Syn, by Townes & Chiu,1970.

Xanthopimpla xanthostigma Girault, 1925. *Insecutor Inscitiae Menstruus*13:38. ♀. des. Type: ♀ Australia: Amamoor forest (Brisbane). Syn, by Townes & Chiu,1970.

Xanthopimpla xara Cheesman, 1936. *Trans. R. Ent.Soc. :* 85:179. ♀. des., fig. Type: ♀, New Hebrides Is: N.E Malekula (London). New Hebrides Is: South West Bay on Malekula. Syn,by Townes & Chiu,1970.

Xanthopimpla sp. Townes, 1947. *Results of an entomological inspection tour of Micronesia*. Mimeographed p.47. Micronesia: Yap; Palau.

Metopius sesamiae Rao, 1953. *Indian Forest. Rec*. (n.s., Ent.) 8:184. des., fig. Type, India : Bengaluru (Dehra Dun). Syn,by Townes & Chiu,1970.

Xanthopimpla spp. Krishnamurti and Usman, 1955. *Indian Jour. Ent*. 16:333. India: Bengaluru; Mandya.

Xanthopimpla sesamiae Townes, Townes and Gupta, 1961. *Mem. Amer. Ent. Inst* 1:67.n.comb.

Diagnosis: Stigma light brown; areola receiving costula behind the centre; areola 0.82 to 1.35x as long as wide.

Distribution: This species has been previously recorded from Karnataka, Kerala and Tamil Nadu (Townes and Chiu, 1970).

Material examined: 1♀, INDIA: Kerala, Kozhikode, Nanminda (N11˚42′23″- E 75˚83′16″), Manjusha B.M, 12.v.2016; 4♀, INDIA: Kerala, Thrissur (N10˚52′76″- E76˚21′44″), Beena P, 1.v.1998; 6♀, INDIA: Kerala, Malappuram, Calicut University campus (N11˚70′20″- E75˚51′22″), Sudheer K, 30.iv.2001; 1♀, INDIA: Kerala, Malappuram, Calicut University campus (N11˚70′20″- E75˚51′22″), Girish K, 30.iv.2001; 1♀, INDIA: Kerala, Malappuram, Chaliyar (N11˚05′75″- E76˚06′57″), Girish K, 14.iii.2003; 1♀, INDIA: Tamil Nadu, Tiruvallur (N13˚25′44″- E 80˚00′87″), Diravium, 4.iv.2003; 1♀, INDIA: Tamil Nadu, Kanchipuram (N12˚83′41″- E79˚70′36″), Diravium, 2.v.2003; 1♀, INDIA: Kerala, Kannur, Azhikode (N11˚91′70″- E75˚33′53″), Sudheer K, 16.ii.2003; 1♂, INDIA: Kerala, Kannur, Azhikode (N11˚91′70″- E75˚33′53″), Girish K, 16.ii.2003; 4♀, INDIA: Kerala, Kottayam, Kumarakom (N9^0.61′75″- E76^0.41′00″), Girish K, 17.iv.2004; 3♀, INDIA: Kerala, Kottayam, Kumarakom (N9˚61′75″- E76˚41′00″), Sudheer K, 17.iv.2004; 2♀, INDIA: Kerala, Kottayam, Kumarakom (N9^0.61′75″- E76^0.43′00″), Santhosh.S, 17.iv.2004; 1♀, INDIA: Kerala, Alappuzha, Kayamkulam (N9˚17′48″- E76˚50′13″), Sudheer K, 19.iv.2004; 1♀, INDIA: Kerala, Alappuzha, Kayamkulam (N9˚17′48″- E76˚50′13″), Girish K, 20.iv.2004;

1♀, INDIA: Kerala, Alappuzha(N9˚49′80″-E76˚33′88″), Ranjith A.P, 5.ii.2012; 1♀, INDIA: Kerala, Trivandrum, Amaravila (N9˚44′58″-E76˚54′09″), Rajesh K.M, 25.i.2013; 1♀, INDIA: Kerala, Kottayam, Changanassery (N8˚40′67″-E77˚10′82″), Ranjith A.P, 23.i.2013; 2M, INDIA: Kerala, Ernakulam, Mulamthuruthy (N9˚90′03″-E76˚38′44″), Rajesh K.M, 26.i.2013; 1♀, INDIA: Kerala, Malappuram, Perassannnur (N10˚84′94″-E76˚06′52″), Rajesh K.M, 22.iii.2013; 1♀, INDIA: Kerala, Kasaragod (N12˚51′02″- E74˚98′51″), Rajesh K.M, 28.ix.2013; 2♀, INDIA: Kerala, Kannur, Nellikkapalam (N11˚96′26″- E75˚75′64″), Rajesh K.M, 29.xi.2013; 1♂, INDIA: Kerala, Kannur, Kaiveli (N11˚76′85″- E75˚44′38″), Rajesh K.M, 28.xi.2013; 1♂ & 1♀, INDIA: Kerala, Kozhikode, Perambra (N11˚56′39″-E75˚75′64″), Rajesh K.M,10.viii.2014; 2♂, INDIA: Kerala, Perumthuruthy (N9˚41′02″- E76˚52′71″), Rajesh K.M, 25.ix.2014; 1♀, INDIA: Kerala, Kannur, Kudukkimotta (N11˚91′30″- E75˚45′70″), Ranjith A.P, 29.xi.2014; 1♂ and 1♀, INDIA: Kerala, Kottayam, Vazhappally (N9˚45′65- E76˚52′71″), Rajesh K.M, 19.xi.2014; 1♀, INDIA: Kerala, Kozhikode, Thikkodi (N11˚49′51″- E75˚62′38″), Manjusha B.M, 8.x.2015; 1♀, INDIA: Kerala, Kozhikode, Balussery (N11˚44′13″- E75˚82′01″), Manjusha B.M, 16.v.2015; 1♂, INDIA: Kerala, Kannur, Madaippara (N12˚03′23″- E75˚25′66″), Manjusha B.M, 22.v.2016; 1♀ and 1♂, INDIA: Kerala, Idukki, Pambadumshola (N10˚07′34″-E77˚14′58), Ranjith A.P, 2.iv.2016; 1♀ and 1♂, INDIA: Kerala, Kozhikode, Kakkayam (N11˚54′72″- E75˚89′26″), Manjusha B.M, 20.x.2016.

CUNEATA SPECIES GROUP

Diagnosis: Lower front corner of the pronotum a round angle of about 135˚; mesoscutum with sparse hairs; scutellum conical or pyramidal, lateral flange reaching the apex; subtegular ridge sharp; fore wing with areolet closed; largest bristles of mid and hind tarsal claws distinctly widened, black apically; hind tibia with some small apical bristles; propodeum with pleural area divided into two areas by posterior transverse carina; ovipositor sheath 0.2 - 0.3x hind tibia.

***Xanthopimpla clivulus clivulus* Townes & Chiu, 1970 (Plate 1, Fig. c)**

Xanthopimpla clivulus clivulus Townes & Chiu, 1970. Mem. Amer. Ent. Inst., 14: 161. ♀. key, des., fig.

Diagnosis: Eyes deeply notched near the antennal sockets; scutellum strongly convex; juncture of lateral longitudinal carina with costula little raised than juncture of lateral and apical transverse carina; mesoscutum with 3 transverse markings, middle one notched, a single spot on posterior end, a pair of black spot on propodeum (1st two lateral area), T1-T6; a transverse band in T7, T8 with two light brown spot, apex of all hind tarsomere light brown, two transverse band on hind femur and tibia.

Distribution: Previously recorded from Malaya, Java and Borneo (Townes & Chiu, 1970).

Material examined: 1♀, INDIA: Kerala, Idukki, Pambadumshola (N10˚07′34″- E77˚14′58″), Ranjith A.P, 8.iv.2016.

Remarks: This species is recorded for the first time from the Southern Western Ghats also this sub sp. recorded for the first time from India.

ELEGANS SPECIES GROUP

Diagnosis: Lower anterior corner of pronotum a sharp angle of 90° - 100°; mesoscutum with sparse hairs on anterior part, notaulus moderately long and deep; scutellum strongly convex, lateral carina extending to apex; fore wing with areolet closed, receiving second recurrent vein at very near apex.

Distribution: Karnataka, Kerala and Tamil Nadu

***Xanthopimpla elegans* (Vollenhoven), 1879**

Pimpla elegans Vollenhoven, 1879. *Stettin. Ent. Ztg*. 40: 147. Holotype: ♀, Indonesia: Java (RMNH).

Xanthopimpla elegans: Krieger (1914). *Arch. f. Naturgesh*. (A)80(6):14.n.comb.

Pimpla apicipennis Cameron, 1899. *Mem. & Proc. Manchester Lit. Phil. Soc*. 43 (3): 161. Holotype: ♀, India: Khasi Hills in Assam (OUMNH). syn.by Krieger, 1914.

Xanthopimpla elegans apicipennis: Townes & Chiu (1970). *Mem Amer. Ent.Ins*., 14:247. ♂, ♀. n.status, key, syn. des., fig. Syn.by Pham, 2011.

Diagnosis: Mesoscutum with three continuous black spots on anterior end and one black mark in front of scutellum; areola closed; punctures on upper half of mesopleuron small to medium sized; T1, T3, T5, and T7 always with large black spots or with black bands; ovipositor sheath about 1.0 - 1.5x hind tibia.

Remarks: In Oriental region, three subspecies are recognized: *X. e. elegans* Vollenhoven from India, Sri Lanka, Myanmar, Thailand, Vietnam, Malaysia, Singapore, and Indonesia, *X. e. cristaminor* Townes & Chiu from the Philippines, and *X. e. insulana* Krieger from Taiwan. There are four subspecies recognized in this present study differing in size of thoracic punctures, colour pattern and length of ovipositor, including two new subspecies and one new report (*X. e. cristaminor*) from the southern Western Ghats.

KEY TO SUBSPECIES OF *XANTHOPIMPLA ELEGANS* (VOLLENHOVEN) OF THE SOUTHERN WESTERN GHATS

1. Mesopleural punctures 0.6 x the distance between the spots, close and coarse; ovipositor sheath <1.5x long as hind tibia..... …....……*X. e. kadnurensis* sub sp.nov.
— Mesopleural punctures 0.1x the distance between the spots, shallow; ovipositor sheath equal or >1.5x long as hind tibia ……2
2. Mesoscutum with punctures 0.5x distance between the spots on front half of lateral lobe; apex of fore wing faintly infuscate ……....*X. e. cristaminor* Townes & Chiu
— Mesoscutum with punctures 0.2 x distance between the spots on front half of lateral lobe; apex of fore wing distinctly infuscate ……..……..……3
3. T2 with paired black spot; segments 1-2 of hind tarsus largely infuscate …… ……..….*X. e. elegans* (Vollenhoven)
— T2 yellow; segments 1-2 of hind tarsus yellow.....…*X. e. priyadarsanani* subsp.nov.

a) ***X. elegans cristaminor* Townes & Chiu, 1970 (Plate 2, Fig. e)**

Xanthopimpla elegans cristaminor Townes & Chiu, 1970. *Mem. Amer. Ent. Inst*., 14: 251. Holotype: ♀. San Luis, Philippines (USNM)

Diagnosis: Punctures on front half of lateral lobe of mesoscutum 0.5 x distance between the spots; areola wider than long, all tergites with pair of spots or transverse band; hind tarsus brown except apex of first tergite; mid and hind tibia with 3 apical and 3 pre-apical bristles.

Material examined: 1♀, INDIA: Kerala, Pambadumshola (N10˚07′34″- E77˚11′51″), Ranjith A.P, 8.iv.2016.

b) ***X. elegans elegans* (Vollenhoven), 1879 (Plate 1, Fig. a)**

Pimpla elegans Vollenhoven, 1879. *Stettin. Ent. Ztg*. 40: 147 .♀. des. Type: ♀, Java. (RMNH)
Xanthopimpla claripennis Cameron, 1905c. *Jour. Straits Branch Roy. Asiatic Soc*. 44: 119. [♀]. des. syn by Townes & Chiu, 1970.
Xanthopimpla taprobanica Cameron, 1905b. *Spolia Zeylanica* 3: 135. ♀. des. Type: ♀, Ceylon: Kandy (London). syn. by Kreieger, 1914.
Xanthopimpla claripennis Krieger, 1914. *Arch. F. Naturgesch*. (A) 80 (6): 14. des. syn by Townes & Chiu, 1970
Xanthopimpla elegans Krieger, 1914. *Arch. F. Naturgesch*. (A) 80 (6): 15. des.
Xanthopimpla melampus Krieger, 1914. *Arch. F. Naturgesch.* (A) 80 (6): 23, 105. B&, ♀. key, des., fig.syn by Townes & Chiu, 1970.
Xanthopimpla interrupta Krieger, 1914.*Arch. F. Naturgesch*. (A) 80 (6): 23, 107. ♀. key, des., fig. syn by Townes *et al*., 1961.
Xanthopimpla elegans elegans Townes & Chiu, 1970. *Mem. Amer. Ent.Inst*., 14:249. M, F.n.status, key, syn., des., fig.

Diagnosis: Mesoscutum with 3 separate spots on anterior end, middle one notched, all tergites with a pair of spots or transverse band, mid and hind tibia with 4 apical and pre- apical bristles.

Material examined: 1♀, INDIA: Kerala, Kollam, Erikkapara (N8˚54′54 - E77˚06′28″), Priyadarsanan D. R, 5.ii.2009; 1♀, INDIA: Kerala, Kannur, Aralam, Pookkundu (N11˚56′02″- E75˚48′22″); Seena K, 13.iv.2009; 2♀, INDIA: Kerala, Kollam, Erikkapara (N8˚54′54″- E77˚06′28″), Priyadarsanan D. R, 9.iv.2009; 1♂, INDIA: Kerala, Kannur, Aralam, Pookkund (N11˚56′02″- E75˚48′22″), Seena K, 13.iv.2009; 1♀ and 1♂, INDIA: Kerala, Kollam,

Erikkapara (N8˚54′54″- E77˚06′28″), Priyadarsanan D. R, 18.iii.2009; 1♀, INDIA: Kerala, Kollam, Erikkapara (N8˚54′54″- E77˚06′28″), Priyadarsanan D. R, 5.ii.2009;1♀, INDIA: Kerala, Janakikkadu (N11˚63′15″- E75˚78′61″), Ranjith A.P, 24.iv.2015; 1♀ & 1♂, INDIA: Kerala, Wayanad, Mananthawady (N11˚76′92″- E75˚98′27″), Manjusha B.M, 22.ii.2016.

c) ***X. elegans priyadarsanani* subsp. nov. (Plate 2, Fig. a)**

Diagnosis: Mesopleural punctures 0.1 x the distance between the spots, mid and hind tibia with 3 apical and 3 pre-apical bristles; all tergites except 2 with pair of spots or transverse band; mid and hind last 2 tarsomere black; ovipositor sheath 1.5 x as long as hind tibia.

Description: Holotype: Female body length: 12 mm (Including ovipositor)

Head: In dorsal view HL = 2.2 mm and HW = 0.3 mm, in front view HL = 1.52 mm and HW = 2 mm; face uniformly punctate, punctures shallow, with hairs, frons with deep groove between antennal socket; clypeus minutely punctate hairy, apex projected forward, hairs longer than face; mandible and malar space densely pubescent; malar space 0.8 x basal width of mandible; inter ocellar distance 0.9x ocello-ocular distance, 0.67x distance between median and lateral ocelli; vertex smooth, a median groove between 2 median ocelli, margin of face in front portion projected forward so that clypeus located below; antenna with 37 segments, scape1.2x as long as width, 1x as long as pedicel, pedicel 0.2x as long as F1, F1 1.23x as long as F2, 7x as long as its width, 4.78x as long as F37, F2 1x as long as F3.

Mesosoma:1.52x as long as head length in dorsal view, 1.75x as long as width between tegula; pronotum polished, hind corner of pronotal margin form a conical projection near front coxa; mesoscutum with shallow punctures, hairs present, notauli distinct and deep, reaches up to tegula; scutellum strongly convex, lateral carina reaches the apex of scutellum; mesopleuron minutely punctate on upper anterior portion, speculum smooth and shiny, lower posterior region with uniform shallow punctures, hairy; metapleuron polished impunctate, hairs on posterior end, sub metapleural carina complete; propodeum polished impunctate without hairs; legs hairy, mid and hind tibia with 3 apical and 3 preapical bristles; nervulus opposite to basal vein; FWL = 9 mm, HWL = 6 mm , FWW = 2 mm , HWW = 1.8 mm.

Metasoma: T1 1x as long as apical width, 1.1x length of T2; first and T2 smooth and shiny impunctate without hairs, T3 - T8 with shallow uniform punctures hairy, median dorsal carina reaches beyond spiracle, lateral carina not reaches spiracle, ventro lateral carina complete; ovipositor length = 4.1 mm, lower valve with ridges ovipositor slightly curved at apex; ovipositor sheath 1.52x long as hind tibia.

Colour: Predominantly yellowish with following black marks :Ocellar region continuing with occipital region (upper portion), 3 fused spots on mesoscutum, one spot on posterior end, transverse band in propodeum, and T1, T3, T7, pairs of spots on T4, T5 and T6, small spot on T8, apex of trochanter, transverse band on hind femur. Marking on mid tibia, apex of mid tibia, and hind tibia, last two tarsal segments of mid and hind tibia, ovipositor, and ovipositor sheath marked with brown.

Male: Unknown; **Host**: Unknown; **Biology**: Unknown

Material examined: Holotype: 1♀, INDIA: Karnataka, Coorg, Kadnur (N12˚21′97- E75˚47′93″), Priyadarsanan D. R, 30.ix.2005.

Distribution: Karnataka (Coorg)

Remarks: *X. e. priyadarsanani* subsp. nov. closely related to *X. elegans elegans* in having faintly infuscate wing but differs from *X. e. elegans* in the characters depicted in the key. This new subspecies differs from *X. e. kadnurensis* subsp. nov. in having small and shallow mesopleural punctures.

Etymology: The new subspecies is named after the collector of the specimen, Dr. Priyadarsanan who has also inspired for the completion of the study.

d) ***X. elegans kadnurensis* subsp. nov. (Plate 2, Fig. b)**

Diagnosis:Mesopleural punctures close and coarse; T2 and T8 entirely yellow, T1,T3,T4,T5,T6

and 7 with a pair of spot or transverse band; ovipositor sheath 1.3x longer than hind tibia.

Description: Holotype: Female body length: 9 mm (including ovipositor)

Head: In dorsal view HL= 1.4 mm and HW= 0.3 mm; in front view HL=1mm and HW = 1.3 mm; face coarsely punctate, with hairs; clypeus minutely punctate, hairy, apically conical; malar space 1.2 x basal width of mandible; inter-ocellar distance 0.72 x ocello-ocular distance, 0.5 x distance between median and lateral ocelli; vertex smooth; antenna with 38 segments, scape1.6x as long as width, 0.9x as long as pedicel, pedicel 0.3x as long as F1, F1 1.1x as long as F2, 6x as long as its width, 3x as long as F38, F2 1x as long as F3.

Mesosoma: 1.42x as long as head length in dorsal view, 1.53x as long as width between tegula; pronotum smooth; mesoscutum with shallow punctures, hairs present, notauli distinct and deep; scutellum moderately convex, lateral carina reaches the apex of scutellum; mesopleuron with moderate punctures on upper anterior portion, speculum smooth and shiny, lower posterior region with moderate punctures, hairy; metapleuron minutely punctate, submetapleural carina complete; propodeum polished impunctate, with all carina; legs hairy; nervulus opposite to basal vein ; FWL =11 mm; HWL = 8.4 mm; FWW =1.8 mm; HWW = 1 mm.

Metasoma: T1 1x as long as apical width, 1.2x length of T2; T1 and T2 smooth and shiny impunctate without hairs, T3 - T8 with shallow uniform punctures, hairy, median dorsal carina reaches beyond spiracle, lateral carina not reaches spiracle, ventro-lateral carina complete; ovipositor length = 2 mm, lower valve with ridges ovipositor slightly curved at apex; ovipositor sheath 1.1x long as hind tibia.

Colour: Predominantly yellowish with following black marks: ocellar region continue to occipital region, 3 fused spots on anterior end of mesoscutum, posterior large spot infront of scutellum, transverse band in propodeum, T1, T3 - T7, large spot on hind trochanter, trochantellus, middle region of hind femur. Base of hind tibia, subapical band on hind tibia, last 3 tarsal segments brownish black.

Male: Unknown; **Host**: Unknown; **Biology**: Unknown

Material examined: Holotype: 1♀, INDIA: Karnataka, Coorg, Kadnur (N12˚21′97″-E75˚47′93″), Priyadarsanan D. R, 8.iv.2005.

Etymology: Species epithet is after the locality of collection, Kadnur in Coorg district.

Remarks: *X. e. kadnurensis* subsp. nov.varies from *X. e. priyadarsanani* subsp. nov.in having apex of clypeus punctate and conical, hind coxa with a large black spot,T1, T3, T4 & T7 with black transverse band, T5 with spots tending to fuse; ovipositor length=2mm; ovipositor sheath 1.1x long as hind tibia.

e) *Xanthopimpla nigritarsis* Cameron, 1903

Xanthopimpla nigritarsis Cameron, 1903. *Jour. Straits Branch Roy. Asiatic Soc*. 39: 138. Lectotype: ♀, Malaysia: Sarawak, Kuching (BMNH).

Diagnosis: Outer margin of subtegular ridge evenly convex; mid and hind tibiae without stout bristles; T1, T3, T5 and T7 with large black spots or black bands; ovipositor sheath about 0.3x hind tibia.

Distribution: Previously recorded from West Bengal (Townes & Chiu, 1970).

f) *X. n. wayanadensis* subsp. nov. (Plate 3, Fig. d, e)

Diagnosis: T2, T4 and T6 with pair of large black spots; segments 1- 3 of hind tarsus yellow.

Description

Holotype: Female body length: 10 mm (Including ovipositor)

Head: In dorsal view HL = 0.32 mm and HW = 1.72 mm; in front view HL = 1.56 mm and HW = 1.42 mm; face and frons distinctly punctate, punctures close, interstices smooth and shiny, hairy; margin of eye moderately notched near antennal socket; clypeus flat, hairs longer than in face, impunctate; mandible and malar space with hairs; malar space 0.34 x basal width of mandible; inter-ocellar distance 0.5 x ocello-ocular distance, 1x distance between median and lateral ocelli; vertex and temple smooth and shiny, with only sparse hairs; antenna with 40 segments, scape1.23 x as long as width, 1.5x as long as pedicel, pedicel 0.23 x as

long as F1, F1 1.22x as long as F2, 7.6x as long as its width, 5.3 x as long F40, F21.1x as long as F3.
Mesosoma: 1.34x as long as head length in dorsal view, 2.07 x as long as width between tegula; pronotum sharp angle, smooth and shiny, mesoscutum minutely punctate with small hairs, hairs smaller than in face, scutellum convex, impunctate, polished, lateral carina reaches the apex; propodeum impunctate, smooth and shiny; mesopleuron with minute punctures on upper anterior and lower posterior, speculum smooth and shiny; metapleuron impunctate, polished, submetapleural carina complete; nervulus opposite to basal vein, not intercepted below; FWL = 8 mm; HWL = 4.85 mm; FWW = 1.8 mm; HWW = 1.1 mm.
Metasoma: T1 1x as long as apical width, 0.97x length of T2; T1 with median dorsal carina reaches behind spiracle, impunctate smooth and shiny, T2 with small shallow punctures, hairs present; T3-T5 with punctures deeper than in T2, T6 - T7 with shallow punctures, hairy; ovipositor sheath 1x long as hind tibia.
Colour: Yellow with black markings on ocellar region, occipital area, 3 long spots on mesoscutum, one spot on posterior end, pairs of black spot in propodeum and T1- T6, T7 with a spot united, T8 with one spot, apex of hind tibia marked with black, 2 spot of hind trochanter. Stigma, antenna, 2 transverse band hind femur, mark on hind tibia,wing infuscate at apex, all hind tarsomere yellow except last – 5th light brown.
Male: Unknown; **Host**: Unknown; **Biology**: Unknown
Material examined: Holotype: 1♀, INDIA: Kerala, Wayanad, Mananthawady (N11˚96′72″-E75˚98′27″), Manjusha B.M, 6.ix.2015.
Remarks: This is the first record of *X. nigritarsis* from the Southern Western Ghats. Two subspecies are currently recognized from Oriental region - *X. n. punctiger* Townes & Chiu from the Philippines and *X. n. reciprocata* Townes & Chiu from India. The specimen from present study area differs from *X. n. reciprocata* in having pair of large black spots in T2, T4 and T6. It differs from the Philippine subspecies in having small punctures on lower half of mesopleuron, and is described as a new subspecies *X. n. wayanadensis*.
Etymology: Species epithet is after locality of collection, Wayanad district of Kerala.

g) *Xanthopimpla tricapus impressa* Townes & Chiu, 1970

Xanthopimpla tricapus impressa Townes & Chiu, 1970. *Mem. Amer. Ent. Inst*., 14: 260. Holotype: ♀, Myanmar: Toungoo, Karenni (GBNH).
Diagnosis: Areola closed; propodeum without basal transverse carina so that first and second lateral area confluent; ovipositor sheath equal to length of hind tibia; notaulus 0.6 as long as tegula; T6 entire yellow.
Distribution: Previously recorded from Kerala (Townes & Chiu, 1970)
Material examined: Nil. Photographs of **Type**: 1♀, MYANMAR: Toungoo, Karenni, 3000 ft., iv.14, Micholitz GBNH examined.
Remarks: The diagnosis is based on the original description (Townes & Chiu, 1970) and the Photographs obtained from GBNH.

INCOMPLETA SPECIES GROUP

Diagnosis: Fore wing with areolet open on outer side, second intercubitus completely absent; nervulus basad of basal vein; mesoscutum with moderately dense hairs; scutellum strongly convex, lateral carina extending to apex; mid and hind tibiae with a few preapical bristles; ovipositor sheath about 0.2–0.6x hind tibia.

Xanthopimpla naenia Morley, 1913

Xanthopimpla naenia Morley, 1913. *Faun. British India, Hymenoptera*, 3(1): 115. Holotype: ♀, India (OUMNH).
Xanthopimpla imprefecta Krieger,1914 *Arch. f. Naturgesch*., (A) 80(6): 23. Key; (A) 80(7):143. ♂, ♀. Des., fig. syn. By Townes & Chiu, 1970.
Diagnosis: Punctures on face moderate size; propodeum with areola partly or completely separate from second lateral area; mesoscutum medially with three continuous black spots; femur entirely yellow.
Distribution: Previously recorded from Tamil Nadu (Townes & Chiu, 1970)
Material examined: Nil. Photographs of **Holotype** - 1♀, TAIWAN: Townes (Data available from the label) USU examined.

Remarks: The diagnosis is based on the original description (Morley, 1913) and the Photographs obtained from the USU collection, Logan.

NANA SPECIES GROUP

Diagnosis: Mesoscutum with sparse hairs, short notaulus, not extending to anterior level of tegula; scutellum convex, lateral flange extending to apex; propodeum with apical transverse carina absent or present as two lateral stubs, areola not defined; pleural area not divided; largest bristles of mid and hind tarsal claws distinctly widened, curved and blackened apically; fore wing with areolet closed.

Xanthopimpla alternans Krieger, 1914 (Plate1, Fig. e)

Xanthopimpla alternans Krieger, 1914. *Arch. f. Naturgesch*., (A) 80(6): 31. Holotype: ♀, Taiwan: Chiayi (GBNH). Lectotype ♀, India designated by Townes & Chiu, 1970.
Xanthopimpla genualata Krieger, 1914. *Arch. f. Naturgesch*. (A) 80 (6): 32. key; (A) 80 (7) : 100. ♀. des., fig. syn.by.Townes & Chiu,1970.
Diagnosis: Propodeum with apical transverse carina present as two small stubs laterally; hind femur black apically; T1, T3, T5 and T7 with black band or black spots; ovipositor sheath about 1.04x hind tibia.
Distribution: Previously recorded from Karnataka, Kerala, Tamil Nadu (Townes & Chiu 1970).
Material examined: 1♀, INDIA: Kerala, Wayanad, Vythiri (N11°55′16″-E76°04′02), Jobiraj, 23.v.2002; Photographs of Type- 1♀, FORMOSA: Kagi, 26.08.07, Hans sauter GBNH.

Xanthopimpla glaberrima Roman, 1913

Xanthopimpla glaberrima Roman, 1913.*Arkiv för Zool*. 8(15): 22. ♀. key, des, Type: ♀, Philippines (NHRS)
Xanthopimpla sauteri Krieger, 1914. *Arch,. f. Naturgesch*, (A) 80 (6): 31. key; (A) 80 (7): 102. ♀. des. Syn.by Townes & Chiu,1970.
Diagnosis: Mid and hind tibiae with 1–2 preapical bristles; apical transverse carina present as two small lateral stubs; tergites each with two black spots, of which black spots on T 6 always smallest; ovipositor sheath 0.72x hind tibia.
Distribution: Previously recorded from Tamil Nadu (Townes & Chiu, 1970)
Material examined: Nil. Photographs of **Holotype**: 1♀, FORMOSA: Koroton, Hans Sauter, 15.ix.07. (GBNH) examined.
Remarks: The diagnosis is based on the original description (Roman, 1913) and the Photographs obtained from GBNH.

Xanthopimpla nana nana Schulz, 1906 (Plate 2, Fig. d)

Xanthopimpla parva Cameron, 1905b. *Spolia Zeylanica* 3: 136. ♂ . des. Type; ♂, Ceylon: Peradeniya (BMNH). Name preoccupied by Krieger, 1899.
Xanthopimpla nana Schulz, 1906. *Spolia hymenopterologica* p. 114. New name.
Xanthopimpla ornate Szépligeti, 1908. *Notes Leyden Mus.* 29: 254. ♀. key, des. Type: ♀, Java: Semarang (Budapest). Syn.by Townes & Chiu, 1970.
Xanthopimpla pulchella Szépligeti, 1908. *Notes Leyden Mus*. 29: 255. ♀. key, des. Type: ♀, Java: Semerang (Budapest). Syn.by Townes & Chiu, 1970.
Xanthopimpla nana nana Townes & Chiu, 1970. *Mem. Amer. Ent. Inst*., 14: 175. ♀, ♂, n. status. Des, fig.India, Java, Sumatra.
Diagnosis: Lower front corner of pronotum with a sharply rounded angle; mesoscutumwith sparse hairs, notauli small not reaching the line connecting front edge of tegulae; mesoscutum with a transverse black band on which marks on two lateral lobes little widened; upper side of flagellum blackish brown; cutellum convex; propodeum with lateral transverse carina entirely absent, only first two lateral carina present; T1, T3, T4, T5 and T7 with two black spots; hind tibia with 3 to 7preapical bristles; ovipositor sheath about 0.5 to 0.9x as long as hind tibia.
Distribution: Previously recorded from Kerala (Townes & Chiu, 1970)
Material examined: 1♀, INDIA: Kerala, Ernakulam, Angamali (N10°18′49″-E76°37′53″), Manjusha B.M, 15.v.2017; 1♀, INDIA: Kerala, Idukki, Pambadumshola (N10°07′34″-E77°14′58″), Ranjith A.P, 8.iv.2016.

Remarks: There are 4 subspecies recognized previously from this group. Only *X. nana nana* is reported from the Southern Western Ghats.

***Xanthopimpla laticeps liturata* Townes & Chiu, 1970 (Plate 3, Fig. a - c)**

Xanthopimpla laticeps liturata Townes & Chiu, 1970. *Mem. Amer. Ent. Inst*, 14: 181. Holotype: ♀, Penang Island, Malaya (USNM)
Diagnosis: Hind tibia with 4 to 9 preapical bristles; propodeum with apical transvers carina absent; three separate spot on mesoscutum,one spot on infront of scutellum; pair of spots in tergites 1 to 7.
Distribution: Previously recorded from Malaysia; Papua New Guinea; Philippines (Townes & Chiu, 1970).
Material examined: 1♀, INDIA: Kerala, Malappuram, Calicut University campus (N11°70′4″- E75°51′1″), Rajasree, 1.ii.2001.
Remarks: This is the first record of the species from India. Two subspecies have been recognized from this group. *X. laticeps liturata* Townes & Chiu from Malaya and *X. laticeps mitigata* Townes & Chiu from New Guinea.

***OCCIDENTALIS* SPECIES GROUP**

Diagnosis: Lower front corner of the pronotum a broadly rounded angle of about135$^{0;}$ mesoscutum with sparse punctures anteriorly, hairs present, notaulus short, not reaching to anterior level of tegula; scutellum convex, lateral flange extending to apex; largest bristles of mid and hind tarsal claws not widened or blackened apically; propodeum with areola closed or open posteriorly; ovipositor sheath 0.5 to 0.9 x hind tibia.

***Xanthopimpla despinosa despinosa* Krieger, 1914**

Xanthopimpla micraulax Krieger, 1914. *Arch. F. Naturgesch*. (A) 80 (6): 32. Key; (A) 80 (7): 104. ♀. Des., fig. Type: ♀, Sarawak: Lundu (GBNH). Syn.by Townes & Chiu, 1970
Xanthopimpla despinosa Krieger, 1914. *Arch. F. Naturgesch.* (A) 80 (6): 32. Key;(A) 80 (7): 106. ♂. Des., fig. Type: ♂, Sumatra: Sukaranda (MZPW).syn.by Townes *et al*., 1961.
Xanthopimpla despinosa leipephlis Townes & Chiu, 1970. *Mem. Amer. Ent. Inst*., 14: 212. Holotype: ♀. Dawki, Assam India. Syn. By Pham, 2011.
Xanthopimpla despinosa subquatrata Chao, 1997. *Wuyi Sci.J*. 13:46.Holotype: ♀, Malaysia: Malaysia primary forest. Syn. By Pham, 2011.
Xanthopimpla despinosa despinosa Townes & Chiu, 1970. *Mem. Amer. Ent. Inst*., 14: 211. ♂,♀. n. status, Key, syn.des, fig.
Diagnosis: Black marks on mesoscutum long, extending posteriorly upto the margin of scutellum; areola open; T2 and T8 entirely yellow.
Distribution: Previously recorded from Karnataka (Townes & Chiu, 1970).
Material examined: 1♂, INDIA: Kerala, Kannur, Aralam (N11°96′56″- E75°77′20″), Priyadarsanan D.R, 9.vi.2009; 1♂, INDIA: Karnataka, Coorg, Kadnur (N12°21′97″- E75°47′93″), Priyadarsanan D.R, 31.xii.2005.

***Xanthopimpla exigua exigua* Krieger, 1914 (Plate 1, Fig. b)**

Xanthopimpla exigua Krieger. 1914. *Arch. f. Naturgesch.* (A) 80 (6): 41, 100. ♂. key, des., fig. Type: ♂, Sarawak: Lundu (GBNH). Syn.by Townes *et al*., 1961.
Xanthopimpla rimosa Krieger. 1914. *Arch. f. Naturgesch*. (A) 80 (6): 41, 96. ♀. key, des., fig. Type: ♀, Sumatra: Sukaranda (MZPW). Syn.by Townes & Chiu 1970.
Xanthopimpla carinata Krieger. 1914. *Arch. f. Naturgesch.* (A) 80 (6): 41, 98. ♂. key, des., fig. Type: ♂, Sumatra: Sukaranda (MZPW). Syn. By Townes *et al*., 1961.
Xanthopimpla exigua exigua Townes & Chiu, 1970. *Mem.Amer.Inst*., 14: 203. ♂,♀ n. status.
Diagnosis: Areola enclosed by distinct carina; propodeum and T4 & T5 with a pair of black spots; hind tibia with 4 to 7 preapical bristles.
Distribution: Previously recorded from China, Indonesia, Sumatra, Malaysia (Townes & Chiu, 1970 and Wang, 1992).
Material examined: 1♀, INDIA: Kerala, Wayanad, Mananthawady (N11°76′92″-E75°98′27″), Manjusha B.M, 2.vi.2015.
Remarks: This is the new record of this species from India. Three subspecies are recognized in this

group: *X. e. exigua* Krieger from Borneo, Malaya, and Sumathra, *X. e. serosa* Wang from China and *X. e. moluccana* Townes & Chiu from Moluccas and Celebes.

Xanthopimpla honorata honorata (Cameron), 1899

Pimpla honorata Cameron, 1899. *Mem. & Proc. Manchester Lit. Phil. Soc*. 43 (3): 170. ♀. key. des. Type: ♀, India: Khasi Hills in Assam (OUMNH).
Xanthopimpla cera Cameron, 1908. *Ztschr. System. Hymen. Dipt*. 8: 38. ♀. des. Type: ♀, India: Sikkim (London).syn.by Townes & Chiu, 1970.
Xanthopimpla kriegeriana Cameron, 1908. *Ztschr. System. Hymen. Dipt*. 8: 38. ♀. Des. Type: ♀, "Himalayas" (London). syn.by Townes & Chiu, 1970.
Xanthopimpla binghami Cameron, 1908. *Ztschr. System. Hymen. Dipt*. 8: 38. "♂" = ♀. des. Type: ♀, India: Sikkim (BMNH).syn, by Townes & Chiu, 1970.
Xanthopimpla honorata Morley, 1913. *Fauna of British India… Hymenoptera* 3 (1): 134. ♀. key, syn., des. India: Khasi Hills in Assam.n.comb.
Xanthopimpla erythroceros Krieger, 1914. *Arch. f. Naturgesch*. (A) 80 (6): 32. Key; (A) 80 (7); 95, ♂, ♀. des., fig syn.by Townes & Chiu, 1970.
Xanthopimpla eurycephala var*, assamensis* Krieger, 1914. *Arch. f. Naturgesch*. (A) 80 (7): 99. ♂, des. Type: ♂, India: Dimapur- Manipur Road in Assam (Berlin). syn.by Townes & Chiu, 1970.
Xanthopimpla varimaculata Townes, Townes, & Gupta, 1961. *Mem. Amer. Ent. Inst*. 1: 71.syn. (in part).
Xanthopimpla honorata honorata Townes & Chiu, 1970. *Mem.Amer.Inst*., 14: 206. ♂, ♀. Key, syn., des., fig.n.status.
Diagnosis: Areola open; a pair of black spots in propodeum; T1, T3, T5 and T7 each with two black spots; hind tibia with 4 - 7 preapical bristles; ovipositor sheath 0.9x hind tibia.
Distribution: Townes & Chiu (1970) recorded this species from Karnataka, Kerala and Tamil Nadu.
Material examined: Nil. Photographs of **Paratype**: 1♀, INDIA: Mysore, USU Logan examined.
Remarks: Subspecies recognized from this group are *X. honorata honorata* Cameron from China, Taiwan, India, Nepal, Myanmar Laos, Vietnam, Thailand, Malaysia, Singapore, Indonesia and the Philippines; *X. h. munda* Krieger from the Philippines; and *X. h. atriclinata* Chao from Malaysia. The species found in this study keys to *X. h. honorata.* The diagnosis is based on the original description of (Cameron, 1899) and the Photographs obtained from the USU Collection, Logan.

Xanthopimpla proximans Townes & Chiu, 1970

Xanthopimpla proximans Townes & Chiu, 1970. *Mem. Amer. Ent. Inst*., 14: 204. Holotype: ♀. Garjia, U.P, India. (FDAC)
Diagnosis: Space between inner ends of stubs of apical carina of propodeum about 0.8x the stubs; ovipositor sheath 0.6x hindtibia.
Distribution: Previously recorded from Tamil Nadu (Townes & Chiu, 1970).
Material examined: Nil. Photographs of **Holotype**: 1♀, INDIA: Uttar Pradesh, Garjia N.T8, 9.iv.1965 Tikar coll. (Gupta), FDAC examined.
Remarks: The diagnosis is based on the original description of (Townes & Chiu 1970) and the Photographs obtained from FDAC.

PUNCTATA SPECIES GROUP

Diagnosis: Lower front corner of the pronotum rounded; mesoscutum with sparse hairs anteriorly, posteriorly almost hairless; notaulus reaching about to a line connecting front edge of tegulae; scutellum convex, lateral flange reaching to apex; propodeum with areola closed, wider than long; fore wing with areolet closed; largest bristles on mid and hind tibia claws weakly widened, pale subapically; ovipositor sheath 1.4 - 2.4x long as hind tibia; ovipositor stout, distinct decurved, gradually tapered to apex.

Xanthopimpla punctata (Fabricius), 1781 (Plate 2, Fig. c)

Ichneumon punctatus Fabricius,1781. *Species insectorum* 1:437 . [♂]. des.Type: ♀, India: "coromandel" (ZMUC).

Pimpla punctata Fabricius, 1804. *Systema piezatorum* p .119. syn.,des. n. comb.India: "coromandel."

Pimpla puncator Smith, 1858. *Jour. Of proc . Linn. Soc. London,Zool.* 2: 119.Misdet. Of *punctator* Linnaeus. Sarawak.

Pimpla transversails Vollenhovan, 1879. *Stettin. Ent. Ztg.* 40:146. ♂. ♀. des.Lectotype: ♀, Sumatra (Leiden). Borneo. Lesser Sunda Is: Timor. syn. by Krieger, 1914.

?pimpla transversalis var. Punctata (?) Vollenhoven, 1879. *Stettin.* Ent. Ztg. 40: 146.syn., des. Lesser Suda Is.: Timor.

Pimpla ceylonica Cameron, 1899. *Mem. & Proc. Manchester Lit. Phil. Soc.* 43 (3): 165. [♂]. key, des. Type: ♂, Ceylon: Trincomalee (London).Syn.by Morley, 1913.

Xanthopimpla punctata Krieger, 1899. *Sitzber. Naturf. Gesell. Leipziug* 1897/ 98: 101. ♀. key, syn., des. Celebes: Toli Toli.n.comb.

Xanthopimpla ruficornis Krieger, 1899. *Sitzber. Naturf. Gesell. Leipzig* 1897/ 98: 103. ♂. key, des. Type: ♂, Molucca Is.: Kai (Berlin). Syn.by Townes & Chiu, 1970.

Zanthopimpla (!) *appendiculata* Cameron, 1902. *Fauna & Geogr.Maldive & Lccadive Archip.*1 (1): 51. ♂, ♀. Lectotype: ♀, Laccadive Is.: Minikoi (London).syn. by Krieger, 1914.

Xanthopimpla brunneciornis Cameron, 1903. *Jour. Straits Branch Roy. Asiatic Soc.* 39:139. ♀. des. Lectotype: ♀, Sarawak (London). syn. by Krieger, 1914.

Xanthopimpla kandyensis Cameron, 1905. *Spolia zeylanica* 3: 136. ♀. des.Type: ♀, Ceylon: Kandy (London). syn. by Krieger, 1914.

Xanthopimpla maculiceps Cameron,1905a. *Tijdschr. v. Ent.*48:37. ♂.des. Type: ♂, Java: Pasuruan (Amsterdam). syn. by Krieger, 1914.

Xanthopimpla lissonota Cameron, 1906. *Jour. Straits Branch Roy. Asiatic Soc.* 46: 115. ♀. des. Type: ♀, Saawak: Kuching (London).syn.by Townes *et al*., 1961.

Xanthopimpla punctator Schmiedeknect, 1907. *Genera Insectorum* 62: 40.n.comb.syn. (in part).

Neopimpla punctata Kuroiwa, 1926. Provisional list of the Hymenoptera collected in Loochoo determined by Dr. Matsumura p. 1. *Nomen nudum. Ryukyu Is.: Okinawa.*

Xanthopimpla kriegeri Szeplgeti, 1908. *Notes Leyden Mus.* 29:255. ♂, ♀.Name preoccupied by Ashmead, 1905. Key, des. Lactotype: ♀, Java: Semarang (Budapest). syn. by Krieger, 1914.

Xanthopimpla kriegeri var.Szepligeti, 1908. *Notes Leyden Mus.* 32:101. ♀. des. Java: Semarang.

Xanthopimpla punctata (as *punctuator* on p. 275) Roman, 1912.*Zool Bidr. Uppsala* 1:268, 275. syn. *Neopimploides syleptae* Viereck, 1912. *Proc. U.S. Batl. Mus.* 42: 151. ♀. des. Type: ♀, India: Malebannur in Mysore (Washington). syn. by Krieger, 1914.

Xanthopimpla trimaculata Matsumua, 1912. Thousand insects of Japan, supplement 4: 145. ♂, ♀. Misdet. Of *trimaculata* Smith. des. Japan: Kyushu. Ryukyu Is.: Okinava.

Xanthopimpla transversalis Morley, 1913. *Fauna of British India... Hymenoptera 3* (1): 122. ♂, ♀. Key, des.syn.by Townes & Gupta,1961.

Xanthopimpla kandiensis Morley, 1913. *Fauna of British India... Hymenoptera 3*(1): 123. ♂, ♀. Key, des. India: Bombay. Ceylon: Kandy; Coloimbo. Emendation.

Xanthopimpla tibialis Morley,1913: *Fauna of British India... Hymenoptera 3 (1): 124.* ♀. key, des. Type: ♀, India: Chapra in Bihar (London). syn.by. Townes, Townes & Gupta, 1961.

Xanthopimpla appendiculata Morley, 1913. *Fauna of British India... Hymenoptera* 3 (1): 139. ♂, ♀. key, des. Laccadive Is.: Minikoi. Syn.by Townes & Gupta,1961.

Xanthopimpla syleptae Krieger, 1914. *Arch. F. Naturgesch.* (A) 80 (6): 19. syn., des. N.comb.

Phygadenon (!) punctuator Ishida, 1915. Report of the sugar cane borer in Formosa 1: 106; 2: pl. 16. ♂, ♀. Name preoccupied by (Linnaeus) Schmiedeknecht, 1907.des., fig. Types: ♂,♀, Taiwan (Sapporo). syn.by Uchida, 1932.

Theronia transversalis Dammerman, 1929. *The agricultural zoology of the Malay Archipelago* p. 144.Syn.by Townes & Gupta,1961.

Xanthopimpla pyraustae Rao, 1953. *Indian Forest Rec.* (n. s., Ent.) 8: 163. ♀. des., fig. Type: ♀, India: New Forest, Dehra Dun in U. P. (Dehra Dun). India: Kannoth Range, Wayanad in Madras. Syn. by. Townes & Chiu, 1970.

Diagnosis: Mesoscutum with fused spots on anterior; areola complete, 0.5–0.7x as long as wide;

T1, T3, T5, and T7 always with a pair of black spots.

Distribution: Widely distributed in India.

Material examined: 1♀, INDIA: Kerala, Wayanad, Mananthawady (N11˚76′92″- E 75˚98′27″), Manjusha B.M, 1.viii.2016; 1♀, INDIA: Kerala, Kannur, kottiyoor forest (N11˚50′21″- E 75˚40′), Girish k, 17.ii.2007; 1♀, INDIA: Kerala, Thrissur, Peechi (N10˚31′21″-E76˚15′01″), Das K.M, pupal parasite larva of leaf roller; 1♀, INDIA: Karnataka, Mangalore (N12˚91′41″- E 74˚85′59″), Sujatha, 17.viii.1999; 1♀, INDIA: Kerala, Malappuram, Calicut University campus (N 11˚70′20″- E 75˚51′22″), Balamani, 14.v.2001; 1♀, INDIA: Kerala, Thrissur (N10˚52′96″-E76˚21′44″), Ushakumari, 15.v.2001;1♀, INDIA: Kerala, Malappuram, Calicut University campus (N 11˚70′20″- E 75˚51′22″), Divakaran, 12.ix.2001; 1♀, INDIA: Kerala, Malappuram, Calicut University campus(N11˚70′20″- E75˚51′22″), shuba, 31. xii.2002; 1♀, INDIA : Karnataka, Bengaluru (N12˚97′15″- E77˚59′45″), Sinu P.A, 21.xii.2002; 1♀,INDIA: Karnataka, Sringeri (N13˚41′97″- E75˚25′06″), Sinu P.A, 11.x.2003; 1♂,INDIA: Karnataka, Sringeri (N13˚41′97″- E75˚25′06″), Sinu P.A, 13.x.2003; 1♀, INDIA: Kerala, Kulathupuzha, (N 8˚90′90″- E77˚05′93″), Santhosh S, 9.xii.2004; 1♀, INDIA: Kerala, Trivandrum, Kanyakumari (N8˚05′07″- E77˚30′51″), Priyadarsanan D.R, 1.ix.2005; 1♀, INDIA: Kerala,Trivandrum, Anaikkatty (N11˚10′48″- E76˚76′82″), Priyadarsanan D.R, 19.ix.2005; 1♀, INDIA: Kerala, Trivandrum, Anaikkatty (N11˚10′48″- E76˚76′82″), Priyadarsanan D.R, 1.x.2005;1♀, INDIA: Kerala, Trivandrum, Kanyakumari (N8˚05′07″- E 77˚30′51″), Priyadarsanan D.R., 28.ii.2006;1♀, INDIA: Kerala, Kannur, Aralam (N11˚96′76″- E 75˚77′20″), Priyadarsanan D.R., 14.ii.2009; 1♀, INDIA: Karnataka, Coorg, Kadnur (N12˚12′96″- E75˚48′22″), Priyadarsanan D. R , 31.xii.2005; 1♀, INDIA: Kerala, Ernakulam, Mulamthuruthy (N9˚90′03″- E76˚38′44″), Rajesh K.M,26.i.2013; I♂, INDIA: Kerala, Wayanad, Panamaram (N11˚73′80″-E76˚38′44″), Rajesh K.M, 2.iii.2014; 1♀, INDIA: Kerala, Kozhikode, Kakkayam (N11˚54′72″- E75˚89′26″), Manjusha B.M, 20.x.2016; 1♀,INDIA: Kerala, Kollam, Erikkapara, (N8˚54′54″- E77˚06′28″), Priyadarsanan D.R., 5.ii.2009; 1♂, INDIA: Kerala, Kozhikode, Nanminda (N11˚42′23″- E75˚83′16″), Manjusha B.M, 12.v.2016; 1♂, INDIA: Kerala, Kozhikode, East hill (N11˚29′37″- E75˚77′49″), Ranjith A.P, 1.vi.2015.

Remarks: This is the most abundant species obtained in this study.

REGINA SPECIES GROUP

Diagnosis: Frons without a groove below median ocelli; face nearly always with weak sublateral vertical ridges on each side; mesoscutum with notaulus short, not extending to anterior level of tegula; scutellum evenly convex to conical, lateral flange reaching to apex; propodeum with areola completely bounded by carinae; pleural area with tubercle-like or hill-like in front of spiracle; pleural area not divided by apical transverse carina; fore wing with areolet closed; largest bristles on mid and hind tibia claws weakly to distinctly widened, pale to black subapically.

Xanthopimpla konowi Krieger, 1899

Xanthopimpla konowi Krieger 1899. *Sitzber. Naturf. Gesell. Leipzig* 1897/ 98: 87.♀.key, des. Type: Japan ?. (GBNH).

Xanthopimpla japonica Krieger 1899.*Sitzber. Naturf. Gesell. Leipzig* 1897/ 98: 81. ♀ key, des. Type: ♀, Japan: Yokohama (GBNH). See Uchida, 1928, for true type locality.Syn. by.Townes & Chiu, 1970.

Xanthopimpla anthereae Cameron 1911.*Soc Ent*. 26: 46.♂, key, des Type :♂,India Bengal (Vienna) . Syn. by.Townes & Chiu, 1970.

Xanthopimpla wastoni Cameron, 1911.*Soc Ent*. 26: 46.♂, key, des Type : ♂,India Bengal (Lendon) . Syn. by.Townes & Chiu, 1970.

Pimla punctator Shiraki 1913, Rpt, Culture of the Silk-fish-line worm (Saturnia pyretorum Westwood), p, 194, misdet, of *punctator Linnaeus*, Reference not seen.

Xanthopimpla princeps Krieger, 1914.*Arch f. Naturegesh* (A) 80 (6): 43, 46.♀, key des., fig. Lectotype♀, India: Sikkim (Vienna). Syn. by.Townes & Chiu, 1970.

Xanthopimpla dux Krieger, 1914.*Arch f. Naturegesh* (A) 80 (6): 43, 48. ♀, key des., fig.

Japan: Yokohama. Syn. by.Townes & Chiu, 1970
Xanthopimpla formosensis Krieger, 1914.*Arch f. Naturegesh* (A) 80 (6): 43, 51 key des., fig type taiwan: Chi-Chi [= Chip Chip] (Berlin).Syn.by. Uchida,1928.
Xanthopimpla macrofacyia Krieger, 1914.*Arch f. Naturegesh* (A) 80 (6): 42, 54 ♀,. key des., fig Type India Sikkim (Vienna). Syn. by.Townes *et al*., 1961.
Xanthopimpla grandis Cushman, 1925.*Ent. Mitt* 14: 43 43,♀,♂, key des., biol,Type:♀, Taiwan. Syn.by. Uchida,1928.
Xanthopimpla pedator Matsumura & Uchida, 1926.*Insecta Matsumurana* 1: 74. ♀, ♂, china mainland . India. Japan: Kyushu. RyushuIs .: Okinawa ; Ishigaki. Taiwan Misdetermination of pedator Fabricius, in part. Syn.by Townes & Gupta, 1961.
Xanthopimpla theophilae Rao , 1953. *Indian Forest Rec*. (n.s. Ent.)8: 159.♂, ♀. des .,fig., Type: ♀. India: Musoorie in U. P. (Dehra Dun) .Syn.by. Townes & Chiu1970.
Diagnosis: Mesoscutal crest small; areola receiving costula near middle; scutellum convex; T3 and T4 with relatively sparse, coarse punctures; ovipositor sheath 1.1x hind tibia.
Distribution: Previously recorded from Tamil Nadu (Townes & Chiu 1970)
Material examined:- Nil. Photographs of Type: 1♀: JAPAN, Konowi, Krieger GBNH examined.
Remarks: The diagnosis is based on the original description of (Krieger, 1899) and the Photographs obtained from the GBNH.

Xanthopimpla lepcha (Cameron), 1899

Pimpla lepcha Cameron, 1899 (May 4). *Mem. & Proc. Manchester Lit. Phil. Soc*. 43 (3) : 163.♀.key, des. Type :♀. India : Khasi Hills in Assam (BMNH).
Pimpla indubia Cameron, 1899 (May 4). *Mem. & Proc. Manchester Lit. Phil. Soc*. 43 (3) : 166. ♀. key, des. Type :♀. India : Khasi Hills in Assam (OUMNH).Syn.by. Townes & Chiu, 1970.
Pimpla khasiana Cameron, 1899 (May 4). *Mem. & Proc. Manchester Lit. Phil. Soc*. 43 (3) : 168. ♀.key, des.Type :♀, India : Khasi Hills in Assam (BMNH).Syn.by. Townes & Chiu, 1961.
Xanthopimpla soleata Krieger, 1899 (July 14). *Sitzber. Naturf. Gesel. Leipzig* 1897/98 : 82. ♀. key, des., fig. Type :♀India : Khasi Hiils in Assam (GBNH). Syn, by Townes & Chiu, 1970.
Xanthopimpla pardalis Krieger, 1899 (July 14). *Sitzber. Naturf. Gesel. Leipzig* 1897/98 : 90. ♂. key, des., fig. Type :♂, India : Khasi Hiils in Assam (GBNH). Syn.by. Townes & Chiu, 1970.
Xanthopimpla lepscha Schulz, 1906. *Spoila hymenopterologica*.p.104. Emendation.
Xanthopimpla pedator Morley, 1913. *Fauna of British India... Hymenoptera* 3(1): 116. ♂, ♀. key, syn., des., fig. India. Syn.by Krieger, 1914.
Xanthopimpla khasiana Morley, 1913. *Fauna of British India... Hymenoptera* 3(1) : 135. ♀. key, des., fig. India : Khasi Hills in Assam.n. comb.
Xanthopimpla indubia Morley, 1913. *Fauna of British India... Hymenoptera* 3(1) : 137. ♀. key, des., fig. India : Khasi Hills in Assam.n. comb.
Xanthopimpla lepcha Krieger, 1914. *Arch. f. Naturgesch*. (A) 80 (6) : 16 des.syn.by Townes *et al*., 1961
Xanthopimpla commixta Krieger, 1914. *Arch. f. Naturgesch*. (A) 80 (6) : 45, 67. ♀. key, des., fig. . Type: ♀, India: Khasi Hills in Assam (GBNH). Syn.by. Townes & Chiu, 1970.
Xanthopimpla giochiensis Uchida, 1928. *Jour. factulty Agr. Hokkaidoimp. univ*. 28:65 ♀. key des., fig type: ♀, Taiwain yuchih (sapporo). Syn.by. Townes & Chiu, 1970.
Diagnosis: Front end of notaulus without a sharp edged crest; areola < 1 x long as wide; scutellum with low blunt point at the centre; T8 entirely yellow.
Distribution: Previously recorded from Karnataka (Townes & Chiu, 1970)
Material examined: Nil
Remarks: The diagnosis is based on the original description of (Cameron, 1899). The species is not represented in the present collection.

Xanthopimpla pedator (Fabricius), 1775

Ichneumon punctator Linnaeus, 1767. *Systema naturae... Edition 12*. 1 (2): 935. ♀. des. Type: ♀, Indies (lost). Name preoccupied by Allioni, 1766.
Ichneumon pedator Fabricius, 1775. *Systema entomologiae* p. 828. ♀. des. Type : ♀, India (HMUG).

Pimpla pedator Fabricius, 1804. *Systema piezatorum* p. 114. n.comb.
Ichneumon multipunctor Thunberg, 1822. *Mem. Acad. Imp. Sci. St. Peters-bourg* 8: 262. des. in Key; 1824. 9: 313. Eastern India & "Cape of Good Hope".New name for *pedator.*
Pimpla punctator Vollenhoven, 1879. *Stettin. Ent. Ztg*. 40: 143. syn., des. Java. Sumatra. Borneo. Celebes: Macassar. China : Ningpo.
Xanthopimpla pedator Krieger, 1891. *Sitzber. Naturf, Gessell. Leipzig* 1897/ 98: 64. n.comb.
Xanthopimpla scutata Krieger, 1899. Sitzber. Naturf, Gessell. Leipzig 1897/ 98: 85. Key, des., Type " Kaulun''. [= Hong Kong: Kowloon] (Berlin). Syn.by Townes & Chiu, 1970.
Xanthopimpla punctatrix Schulz, 1906. *Spolia hymenopterologica* p.114 Emendation.
Xanthopimpla punctator Schmiedeknecht, 1907. *GeneraInsectorum* 62: 40.syn. (in part),
Xanthopimpla predator (!) Maxwell - Lefroy & Howiet. 1909 *Indian insect life*' P. 177. fig.
Xanthopimla multipunctor Roman, 1912 .*Zool. Bidr. Uppsala* 1. 267 des..fig
Xanthopimla braueri Krieger, 1914. *Arch . f. Naturgesh*. (A) 80 (6): 43, 58, Key, des. fig. Lectotype : (Labeled by Townes). China mainland, Kiaochow (Kiautschou) [Bay] at Tsingtau (Tsingtau) (Berlin). Syn.by Townes & Chiu, 1970.
Xanthopimla manilensis Krieger, 1914. *Arch . f. Naturgesh*. (A) 80 (6): 43, 62, Key, des. fig. Lectotype: Manila (Berlin). Syn.by Townes & Chiu, 1970.
Diagnosis: Scutellum distinctly conical; areola receiving costula behind the middle; T3–T5 densely, coarsely punctate; female without black spots on T6; ovipositor sheath 0.82x hind tibia.
Distribution: Previously recorded from Karnataka and Tamil Nadu (Townes & Chiu, 1970).
Material examined: 1♀, INDIA: Karnataka, Bengaluru, (N12°96′1″- E77°59′3″) ex.pupa of *Spodoptera litura* xi.1969. (NBAIR).

Xanthopimpla regina Morley, 1913

Xanthopimpla regina Morley, 1913, *Fauna of British India..... Hymenoptera* 3 (1) :118 key, ♂, ♀ des, type: East Pakistan: Sylhet (BMNH). India; Chapra in Bihar: Sikkim. Nepal, Burma: Mandaley.
Xanthopimpla mecrura Krieger, 1914, *Arch, f, Naturgesch*. (A) 80 (6): 19. des.Syn.by. Townes *et al*., 1961.
Diagnosis: T1 entirely yellow; T3 densely, coarsely punctate; ovipositor sheath long, 1.85x hind tibia; ovipositor with about 11 apical transverse ridges.
Distribution: Townes & Chiu
previously recorded this species from Karnataka
Material examined: Nil. Photographs of **Holotype**: 1♀, BMNH (E)962085 (Data as on label) examined.
Remarks: The diagnosis is based on the original description (Morley, 1913) and the Photographs obtained from the BMNH, London.

Xanthopimpla verrucula apheles Townes & Chiu, 1970 (Plate 1 Fig. d)

Xanthopimpla verrucula apheles Townes & Chiu 1970. *Mem. Amer, Ent Inst*. 14:55. Holotype: ♀, Singapore (USNM)
Diagnosis: Punctures on face shallow; areola 1x long as wide; T8 marked with black.
Distribution: Previously recorded from Philippines and Singapore (Townes & Chiu, 1970, Yu *et al.,* 2012).
Material examined: 1♀, INDIA: Kerala, Malappuram, Calicut University campus (N11°70′20″-E75°51′22″), Taha P, 18.v.2000.
Remarks: The species is recorded from India for the first time. One subspecies is recognized in this group. *X. verrucula apheles* Townes & Chiu from Singapore. In this study *X. v. apheles* Townes & Chiu reported first time from the Southern Western Ghats.

STEMMATOR SPECIES GROUP

Diagnosis:Face partially black; T1 0.95 - 1.3 as long as wide; mesoscutum marked with black; notaulus extending to or a little behind anterior level of tegula; scutellum evenly convex, lateral flange extending to apex; propodeum with areola complete, 0.8 -1 .8x as long as wide; hind tibia with 8 to 23 preapical bristles; fore wing with areolet closed; ovipositor moderately stout.

***Xanthopimpla stemmator* (Thunberg), 1824**

Ichneumon stemmator Thunberg, 1822. *Mem, Acad. Imp. Sci. St. Petersbourg* 8:262. key; 1824. 9:313. [♂].des. Type: ♂, China (UUZM).

Pimpla integrata Smith, 1860. *Jour. of proc. Linn. Soc. London, Zool*. 5: 140. ♀. des. Type: ♀, Molucca Is.: Bachan (OUMNH). Syn.by Townes *et al*., 1961.

Pimpla integrator Smith, 1865. *Jour. Linn. Soc. London, Zool*. 8: 64. Molucca Is.: Morotai.

Xanthopimpla ?integreta Krieger, 1899. *Sitzber. Naturf. Gesell. Leipzig* 1897/ 98: 65. N.comb.

Xanthopimpla thoracalis Krieger, 1899. *Sitzber. Naturf. Gesell. Leipzig* 1897/ 98: 95. ♀. key, des. Type: ♀, Molucca Is.: Kai (GBNH).Syn.by. Krieger, 1914.

Xanthopimpla maculifrons Cameron, 1903. *Jour. Straits Branch Roy*. Asiatic Soc. 39: 138. ♀. des. Lectotype: ♀, Sarawak: Kuching (BMNH). Syn.by. Townes & Chiu, 1970.

Xanthopimpla bimaculata Cameron, 1906. *Jour. Starits Branch Roy*. Asiatic Soc. 46: 116.♂, ♀.des. Lectotype: ♀, Borneo (London). Sarawak: Kuching. Syn.by. Krieger, 1914.

Xanthopimpla nursei Cameron, 1907. *Jour. Bombay Nat. Hist. S*oc. 17:592. ♀.des. Type: ♀, India: [Dessa in Bombay] (London). Syn.by. Krieger, 1914.

Xanthopimpla facialis Szepligeti, 1908. *Notes Leyden Mus*. 29: 256. ♂. Key, des. Type: ♂, Java: Semarang (Budapest).Syn.by Krieger, 1914

Pimpla sp. Jacobson, 1909. Jaarverslag van de Topographische Dienst in Nederlandsch Indie 1908: 206A. Krakatau Is. in Sunda Strait.

Xanthopimpla stemmatrix Schulz, 1912. *Berliner. Ent. Ztschr*. 57:65, 98. ♂. Syn., note on type, emendation.

Xanthopimpla stemmator Roman, 1912. *Zool. Bidr. Uppsala* 1: 280. ♂. Des.n. comb

Xanthopimpla Doleshali Krieger, 1914. *Arch. F. Naturgesch.* (A) 80 (6): 34. Key; (A) 80 (7): 10. ♀. des., fig.Lectotype: ♀, Molucca Is. : Amboina (Vienna). Syn.by.Townes & Chiu, 1970.

Xanthopimpla transfuga Krieger, 1914.*Arch. F. Naturgesch*. (A) 80 (6): 38. Key; (A) 80 (7): 10. ♀. Des., fig. type: ♀, Java: Sukabumi, 2000 ft. (Wrsaw). Syn.by.Townes & Chiu, 1970.

Xanthopimpla stemmator var.*confluens* Krieger, 1914. *Arch. F. Naturgesch*. (A) 80 (6): 27. Key; (A) 80 (7): 4. Des. Type: ♂, Philippines: Atimonan on Luzon (Berlin).Syn.by Townes *et al*., 1961.

Xanthopimpla stemmator var. *maulifrons* Strand, 1915. *Arch. F. Naturgesc*h. (A) 80 (8): 1223. Syn.

Habropimpla sesamiae Rao, 1953. *Indian Forest Rec.* (n.s, Ent .) 8: 166. ♂, ♀. des., fig. type: ♀, India: Bengaluru (Dehra Dun). Syn.by *Townes et.al*., 1961.

Diagnosis: Hind slope of vertex with two black spots; hind tibia with 9–16 preapical bristles; propodeum and tergites each with a pair of black spots (except T6 entirely yellow); ovipositor sheath about 1.1x hind tibia.

Distribution: Previously recorded from Karnataka, Kerala and Tamil Nadu (Townes & Chiu 1970).

Material examined: 1♀, INDIA: Uttar Pradesh, Kukrail, vii.1963, ex.pupae of *Polygonum* sp.(From NBAIR collection) det by: G.J Kerrrich; 2 M, INDIA: Bamandauga, 21.viii.1967; 1♀, INDIA: Karnataka, K.R Nagar, 21.xii.1963, ex pupae of *Melanitusismene*; 1♀, INDIA: Uttar Pradesh, Golagokarannath, x.1973,ex pupa of *Sylepta derogata;* 1♀, INDIA:West Bengal,Kalimpong, iii.1963,ex pupae of *Sesamia* sp.; 1♀, INDIA: Kerala, Ernakulam, Kanjiramattom, iii.1963 (NBAIR).

TEREBATRIX SPECIES GROUP

Diagnosis: Lower front corner of pronotum rather sharply to rounded; mesoscutum entirely covered with hairs, notaulus short and deep, not extending to anterior level of tegula; scutellum evenly convex to sharply conical, lateral flange extending to apex; propodeum with areola completely bounded by carinae or rarely confluent laterally with second lateral area; largest bristles on mid and hind tibia claws distinctly widened, blackened subapically; hind trochanter and femur always marked with black.

***Xanthopimpla brevicauda nathani* Townes & Chiu, 1970**

Xanthopimpla brevicauda Cushman, 1925. *Ent. Mitt*, 14: 49. ♀. key des. Type: ♀, Taiwan : Chiahsienpu

Xanthopimpla brevicauda nathani Townes & Chiu, 1970. *Mem. Amer. Ent. Inst*., 14: 152. Holotype: ♀, Walayar Forest, Southern Malabar, India (CNCI)

Diagnosis: Areola wide behind than infront; punctures on T3 and T4 shallow to moderately deep; T2 and T6 with paired black spot; flagella blackish brown; hind femur not marked with black; ovipositor sheath 0.7x hind tibia.

Distribution: Previously recorded from Kerala (Townes & Chiu, 1970).

Material examined: Nil. Photographs of **Holotype**: 1♀, INDIA: Walayar Forest, south Malabar, 1000 ft., India, x.1956, P.S.Nathan (CNCI) examined.

Remarks: One subspecies is recognized in this group. *X. brevicauda nathani* Townes & Chiu from India. The diagnosis is based on the original description (Townes & Chiu, 1970) and the Photographss obtained from the CNCI.

Xanthopimpla conica Cushman, 1925 (Plate 2, Fig. i)

Xanthopimpla conica Cushman, 1925. *Ent. Mitt.,* 14: 45. Holotype: ♀, Taiwan: Kangkou [= Kankau], Hengchun (DEI).

Diagnosis: Scutellum conical with sharp point; median and lateral black marks on mesoscutum almost jointed posteriorly to black mark in front of scutellum, median black mark with deep notch anteriorly; mid and hind tibiae without bristles near apex; tergites each with black band; ovipositor sheath 0.25x hind tibia.

Distribution: Previously recorded from Kerala and Tamil Nadu (Townes &Chiu, 1970).

Material examined: 1♀, INDIA: Kerala, Kozhikode, Kakkayam (N11˚54′72- E75˚89′20″), Manjusha B.M, 8.vii.2015

Xanthopimpla decurtata detruncata Krieger, 1914

Xanthopimpla detruncata Krieger, 1914. *Arch. F. Naturgesch*. (a) 80 (6) : 39, 115, ♂♀. Key, des., fig. Lectotype : (designated by Townes, Townes & Gupta, 1961.) ♀, Taiwan: Fengyüan (GBNH).

Xanthopimpla decurtata detruncata Townes & Chiu, 1970. *Mem. Amer. Inst.*, 14:143, ♂♀. n.status, key,des.,fig. India.

Diagnosis: Face densely and coarsely punctate; base of propodeum with two large black spot; front side of hind femur with sub dorsal black stripe; hind tibia with group of 3 stout bristles; punctures on tergites moderately deep.

Distribution: Previously recorded from Karnataka, Kerala and Tamil Nadu (Townes & Chiu 1970).

Material examined: Nil. Photographs of **Paratype**: 1M, GERMANY: Luzion: Atimonan, Townes and Chiu, 10-31.viii.08, GBNH examined.

Remarks: Only one subspecies is previously recorded. *X. decurtata detruncata* from India, Thailand, Malaysia, Vietnam, and Taiwan. The diagnosis is based on the original description (Krieger, 1914) and the Photographss obtained from the GBNH.

Xanthopimpla polyspila Cameron, 1907

Xanthopimpla polyspila Cameron, 1907b. *Tijdschr. v. Ent.,* 50: 101. Holoype: ♀, India: Sikkim (BMNH).

Xanthopimpla lissonota Cameron, 1907a.*Ann & Mag.Nat.His*.,(7) 20:19. ♂. Name preoccu. By Cameron,1906.des. Type: ♂, Malaysia:Kuching (LONDON). Syn.by Townes & Chiu, 1970.

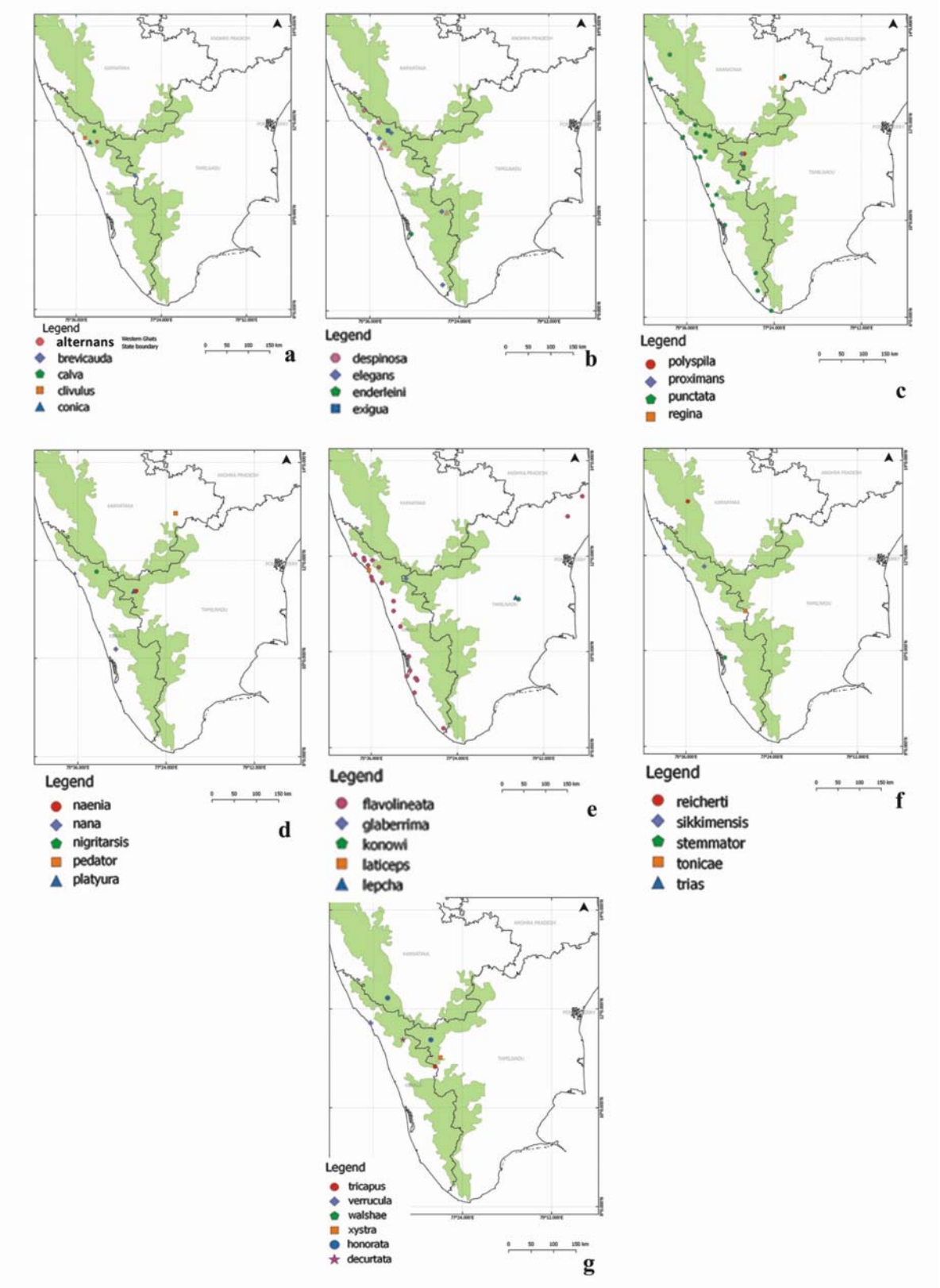
Xanthopimpla leionota Townes, Townes & Gupta, 1961. *Mem.Amer.Ent.Inst*.. 1:58.n.name for *lissonota* Cameron.

Diagnosis: Face moderately punctate; areola usually with two small black spots, receiving costula near its apical 0.35; tergites each with a pair of black spots; ovipositor sheath 1.45x hind tibia.

Distribution: Previously recorded fromTamil Nadu (Townes & Chiu, 1970).

Material examined : Nil

Remarks: Species distributed in India, Java and Taiwan. This species reported from Nilgiri hills by Townes & Chiu. The species is not represented in the present collection.The diagnosis is based on original description.



Map: Distribution of *Xanthopimpla* sp. in the southern Western Ghats

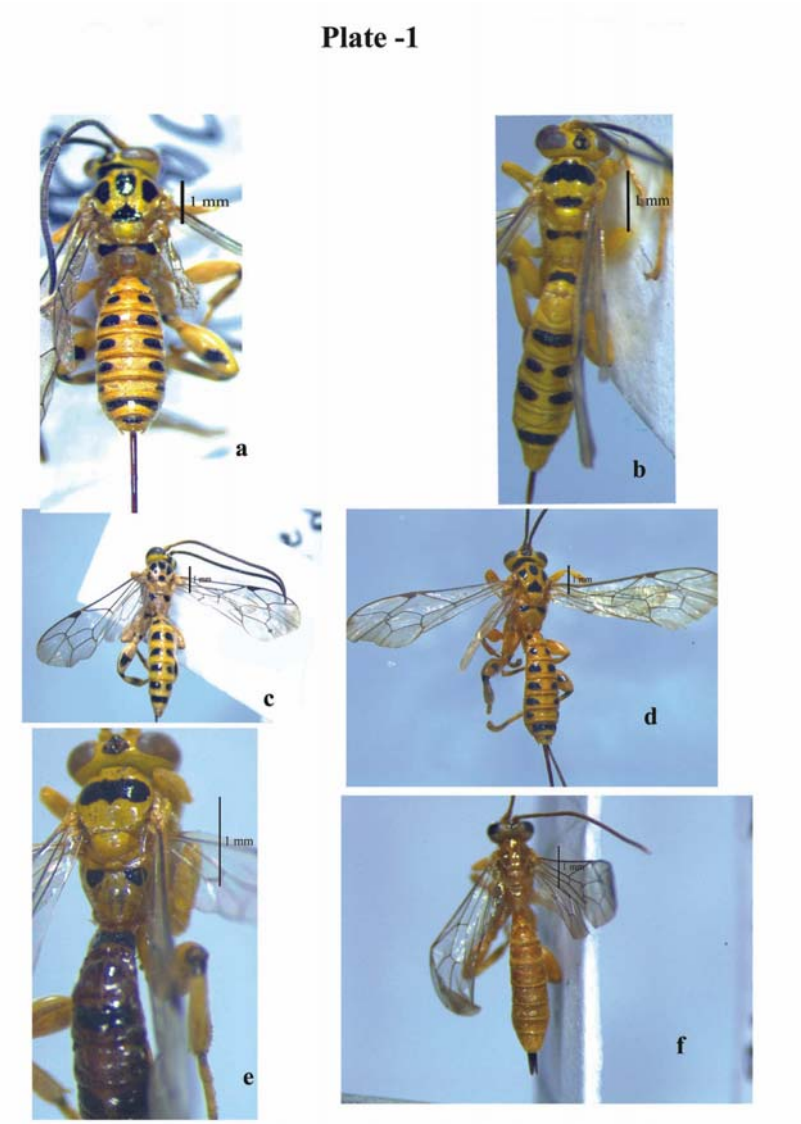


Fig : Dorsal view of a) *X.elegans elegans*, (Vollehoven) b) *X.exigua exigua,* Krieger c)*X.clivulus clivulus* ,Townes & Chiu d) *X.verrucula apheles*, Townes & Chiu e) *X.alternans,* Krieger f) *X. flavolineata,* Cameron.

***Xanthopimpla sikkimensis* Cameron, 1907 (Plate 2, Fig. f)**

Xanthopimpla sikkimensis Cameron, 1907b. *Tijdschr. v. Ent*., 50: 100. Holotype: ♀, India: Sikkim (BMNH).

Diagnosis: Face with small punctures; hind slope of vertex with black area; notaulus deep, not extending beyond the line of connecting front edge of tegula; hind femur with a black mark on front side, hind tibia with black marks anteriorly, posteriorly, apically; propodeum and T1, T3, and T7 with black bands; ovipositor sheath 2.3xlong as hind tibia.

Distribution: Previously recorded from Sikkim (Townes & Chiu, 1970).

Material examined: 1♀, INDIA: Kerala, Wayanad, Mananthawady (N11°76′92″-E75°98′27″), Manjusha B.M, 1.viii.2016.

Remarks: This is the first record of the species from the Southern Western Ghats.

Fig : Dorsal view of a) *X.elegans priyadarsanani* sub sp.n. b) *X.e.kadnurensis* sub sp.n c) *X.punctata* (Fabricius) d) *X.nana nana,* Schulz e) *X.e.cristaminor* , Townes & Chiu f) *X.sikkimensis* , Cameron g) *X.calva sexcincta* ,Townes & Chiu h)*X.trias,*Townes & Chiu i) *X.conica* ,Cushman

***Xanthopimpla tonicae* Townes & Chiu, 1970**

Xanthopimpla tonicae Townes & Chiu, 1970. *Mem. Amer. Ent. Inst*., 14: 153. Holotype: ♀, Walayar forest, South Malabar, India (CNCI)
Diagnosis: Scutellum evenly convex; hind femur with a large black mark on front and hind side, hind tibia with 4 apical bristles and 2 small pre apical bristles; ovipositor sheath 0.27 x long as hind tibia.
Distribution: Previously recorded from Kerala (Townes & Chiu, 1970).

Material examined: Photographs of **Holotype** 1♀, INDIA: South Malabar, viii.1952, Townes & Chiu, CNCI
Remarks: The diagnosis is based on the original description (Townes & Chiu, 1970) and the Photographs obtained from the CNCI Ottawa.

***TRUNCA* SPECIES GROUP**

Diagnosis: Lower front corner of pronotum very broadly rounded, forming an angle of more than

Plate -3

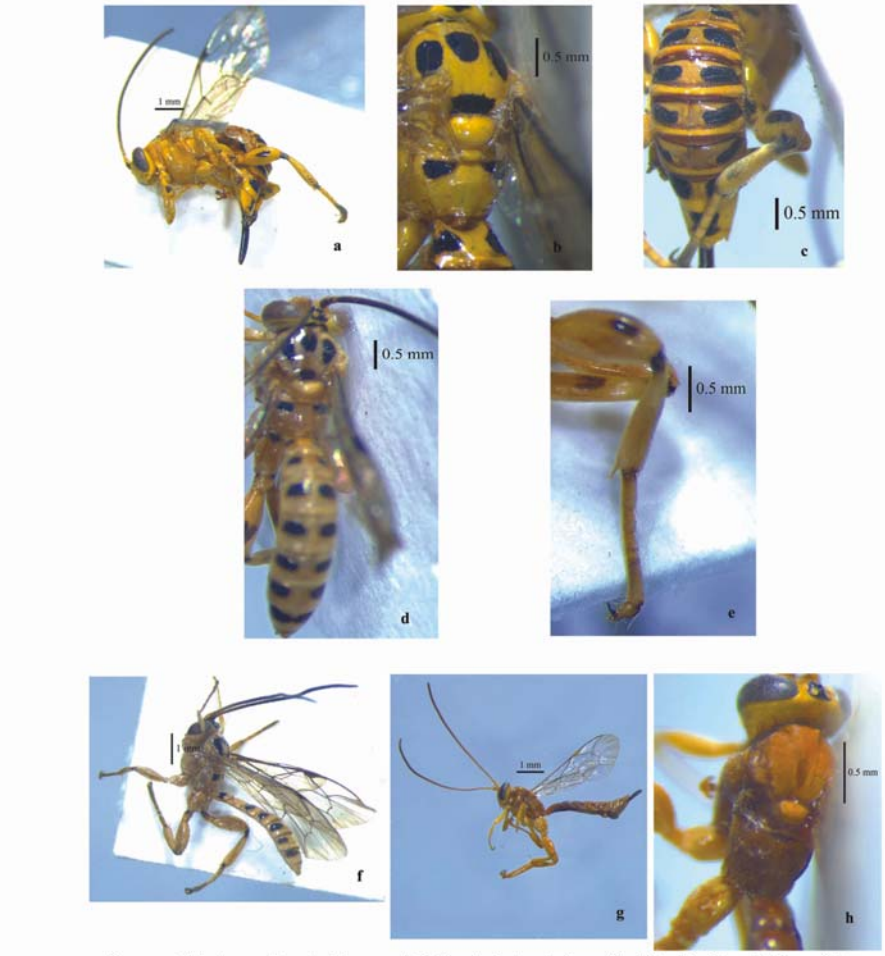


Fig : a- c *X.laticeps liturata,* Townes & Chiu a). Lateral view of habitus b). Dorsal view of thorax c). Dorsal view of T2-T8
d-e: *X.nigritarsis wayanadensis* sub sp.n.d). Dorsal view e). Hind tibia
f).Lateral view of *X.despinosa despinosa,* Krieger
g-h:*X.enderleini,* Krieger g). Lateral view h).Dorsal view of thorax

130°; notaulus usually longer than tegula length; scutellum strongly convex to low conical; propodeal carinae incomplete or entirely absent; fore wing with areolet closed; largest bristles of mid and hind tibia widened apically; T1 with dorsolateral carina complete, strong between spiracle and apex.

***Xanthopimpla calva sexcincta* Townes & Chiu, 1970 (Plate 2, Fig. g)**

Xanthopimpla calva Townes & Chiu, 1970. *Mem. Amer. Ent. Inst.*, 14: 240. Holotype: ♀, the Philippines: Gapan, Nueva Ecija , (CNCI)

Xanthopimpla calva sexcincta Townes & Chiu, 1970.*Mem. Amer. Ent. Inst.*, 14: 241. Holotype: ♂, Malaysia: North Borneo

Diagnosis: Propodeum without carinae, except apical part of lateral longitudinal carina present; first tergite broad, shorter than apical width; T1, T3, T4, T5, and T7 each with two black spots; apex of mid and hind tibia blackish; ovipositor sheath 0.92 x long as hind tibia.

Distribution: Previously recorded from Tamil Nadu (Townes & Chiu, 1970)

Table 1 : Showing the species group, species and sub species of Xanthopimpla Saussure from the Southern Western Ghats

Sl. No	Species Group	Species	Subsp.
1.	Brachycentra	*Xanthopimpla platyura* Townes & Chiu	
2.		*Xanthopimpla reicherti* Krieger	*X. r. reicherti* Krieger
3.		*Xanthopimpla walshae* Townes & Chiu	*X. w. walshae* Townes & Chiu
4.	Citrina	*Xanthopimpla enderleini* Krieger	
5.		*Xanthopimpl aflavolineata* Cameron	
6.	Cuneata	*Xanthopimpla clivulus* Townes & Chiu	*X. c. clivulus*Townes & Chiu
7.	Elegans	*Xanthopimpla elegans* (Vollehoven)	i) *X. e. cristaminor* Townes & Chiu ii) *X. e. elegans* Vollehoven iii) *X. e. kadnurensis* subsp.nov. iv) *X. e. priyadarsanani* subsp.nov.
8.		*Xanthopimpla nigritarsis* Cameron	*X. nigritarsis wayanadensis* subsp. nov.
9.		*Xanthopimpla tricapus*Townes & Chiu	*X. t. impressa* Townes & Chiu
10.	Incompleta	*Xanthopimpla naenia* Morley	
11.	Nana	*Xanthopimpla alternans* Krieger	
12.		*Xanthopimpla glaberrimma* Roman	
13.		*Xanthopimpla laticeps* Townes & Chiu	*X. l. liturata* Townes & Chiu
14.		*Xanthopimpla nana* Schulz	*X. n. nana* Schulz
15.	Occidentalis	*Xanthopimpla despinosa* Kreiger	*X. d. despinosa* Kreiger
16.		*Xanthopimpla exigua* Krieger	*X. e. exigua* Krieger
17		*Xanthopimpla honorata* Cameron	*X. h. honorata* Cameron
18.		*Xanthopimpla proximans* Townes & Chiu	
19.	Punctata	*Xanthopimpla punctata* (Fabricius)	
20.	Regina	*Xanthopimpla konowi* Krieger	
21.		*Xanthopimpla lepcha* (Cameron)	
22.		*Xanthopimpla pedator* (Fabricius)	
23.		*Xanthopimpla regina* Morley	
24.		*Xanthopimpla verrucula* Townes & Chiu	*X. v. apheles* Townes & Chiu
25.	Stemmator	*Xanthopimpla stemmator* (Thunberg)	
26.	Terebatrix	*Xanthopimpla conica* Cushman	
27.		*Xanthopimpla brevicauda* Cushman	*X. b. nathani* Townes & Chiu
28.		*Xanthopimpla decurtata* Krieger	*X. d. detruncata* Townes & Chiu
29.		*Xanthopimpla sikkimensis* Cameron	
30.		*Xanthopimpla polyspila* Cameron	
31.		*Xanthopimpla tonicae* Townes &Chiu	
32.	Trunca	*Xanthopimpla calva* Townes & Chiu	*X. c. sexcincta* Townes & Chiu
33.		*Xanthopimpla trias* Townes & Chiu	
34.	Xystra	*Xanthopimpla xystra* Townes & Chiu	

Material examined: 1♀, INDIA: Kerala, Wayanad, Mananthawady (N11˚76′92″-E75˚98′27″), Manjusha B.M, 20.vii.2015.

Remarks: Three subspecies are recognized, *X. calva calcis* Townes & Chiu from Philippines, *X. c. periscelis* Townes & Chiu from Philippines, and *X.c.sexcincta* Townes & Chiu from India, Myanmar and Malaysia. The specimens collected from the Southern Western Ghats belong to *X. c. sexcincta.*

***Xanthopimpla trias* Townes & Chiu, 1970 (Plate 2, Fig. h)**

Xanthopimpla trias Townes & Chiu, 1970. *Mem. Amer. Ent. Inst*., 14: 243. Holotype: ♀, Mysore, India. CNCI.

Diagnosis: Propodeum without carinae, stubs of pleural carina present; T1, T4, andT7 each with black band, T3 and T5 entirely yellow; ovipositor 0.45x hind tibia.

Distribution: Previously recorded from Karnataka (Townes & Chiu, 1970).

Material examined: 1♀, INDIA: Kerala, Kasargod, Neeleshwar (N12˚27′21″- E 75˚16′32″), Manjusha B.M, 2.vi.2016.

***XYSTRA* SPECIES GROUP**

Diagnosis: Scutellum with a lateral carina only at the basal corner or with none; propodeum long and flattened without carinae; submetapleural carina absent; mid and hind tibiae with many stout bristles; fore wing with areolet closed; ovipositor tip with a few coarse transverse ridge on both upper and lower valve.

***Xanthopimpla xystra* Townes & Chiu, 1970**

Xanthopimpla xystra Townes & Chiu, 1970. *Mem. Amer. Ent. Inst.*, 14: 303. Holotype:♀, Coimbatore, Madras, India.(CNCI)

Diagnosis: Frons with a median elevation; black colour on ocellar area extended into hind slope of vertex; propodeum long and flattened without carina; ovipositor sheath 0.7 x long as hind tibia.

Distribution: Previously recorded from Tamil Nadu, Kerala. (Townes & Chiu, 1970).

Material examined: Photographs of Type: 1F, INDIA: Coimbatore, 1400 ft., Apr.1962 Townes & Chiu. CNCI

Remarks: The diagnosis is based on the original description (Townes & Chiu, 1970) and the Photographs obtained from the CNCI Ottawa.

DISCUSSION

The most relevant work from the Indo-Australian area on the fauna of *Xanthopimpla* Saussure was published by Townes and Chiu (1970), which categorized the genus into 20 species groups, of which 12 are known from the southern Western Ghats. A total of 28 species were documented from the southern Western Ghats. The present study reveals the richness and diversity of the study area. Among the 13 species groups recognized, one species group viz., Cuneata is newly recorded from the southern Western Ghats. Six species are newly recorded from the study area viz, *X. clivulus*, *X. exigua*, *X. laticeps*, *X. nigritarsis*, *X. sikkimensis* and *X. verrucula*. Three new subspecies are also described as part of the study. Thirty four species are documented categorized under thirteen species groups (Table 1). The distribution of the species has been manifested in the map, which clearly reveals the distribution status of the 34 species from the southern Western Ghats.

ACKNOWLEDGEMENTS

The first author is greatly indebted to Dr. D.R. Priyadarsanan, Dr. K. Seena and S. Abhishek of ATREE, Bengaluru for providing the specimens on loan, collection requirements for the study and preparing distribution maps and to A.P. Ranjith, Calicut University for sharing the specimens. We would like to thank Dr. Andrew Bennett, CNC, Ottawa,Ontario; Dr. David Wahl, Utah State University, Logan ; Dr. Elijah J. Talamas, Florida Department of Agriculture, Gainseville, Florida and to Mr. Lukas, Entomology Museum fuer Naturkunde, Berlin, Germany for providing the valuable Photographs of the Type specimens. We are indebted to Dr.V.K. Gupta, Gainesville, Florida; Dr. NhiThi Pham, Vietnam, and Dr. Varga .O. Sasha, Ukraine for providing the relevant literatures. The first author is also thankful to Dr. Ankita Gupta, ICAR - NBAIR, Bengaluru for the support to study specimens, deposited in NBAIR and to Dr. B. Ramesha, College of Agriculture, KAU, Padanakkad for sharing the lab facility. First author acknowledges the authorities of the Department of Zoology, Government College Kasaragod, and the Department of Zoology, The Zamorin's Guruvayurappan College, for providing the laboratory facilities.

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(Received 13 May 2018; revised ms accepted 30 May 2018; published 10 October 2018)

ENTOMON 43(3): 215-218 (2018)
Short Communication No. ent. 43308

Life cycle and seasonal infestation of *Erionota torus* Evans (Lepidoptera: Hesperiidae) on banana in Shimoga, Karnataka

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ABSTRACT: In the present investigation the life cycle, distribution and seasonal infestation of *Erionata torus* on banana crop at two locations viz., Agasavalli and Mandagadde in Shimoga district of Karnataka were studied. Medium number of banana skipper was noted throughout the cropping season. The seasonal incidence was studied from first week of October 2017 to April 2018. During the study, it was found that the percentage of infestation increased from October to February and it gradually decreased. There was a slight variation in the percentage of infestation at both study areas. The current outbreaks in south India may be due to possible climate shifts and non-availability of adequate natural enemies. © 2018 Association for Advancement of Entomology

KEYWORDS: *Erionata torus*, banana crop, distribution and infestation

Erionota species are pest of *Musa* species. Its indigenous range is from Northern India and Southern China to South East mainland Asia. It has spread to Mauritius, Southern Philippines, Taiwan, Japan and Western India. Among the *Erionota* species, *Erionata torus* Evans is common and well known banana pest where their larva lives in the rolled up strips of banana leaves. In India, *Erionota thrax* was reported in Patak and Shriram (1972) from NEH region of India. Outbreaks in south India, especially in Karnataka (Kamala Jayanthi *et al*., 2015; Sharanabasappa and Adivappar, 2016; Onkara Naik, 2016), Kerala (Smitha *et al*., 2015), Tamil Nadu (Padmanaban *et al.,* 2014, 2016), Andhra Pradesh (Shrinivasareddy *et al.,* 2018) were reported and it may be due to the non-availability of adequate natural enemies and possible climate shifts that could have helped the banana skipper population to reach damaging threshold (Raju *et al.,* 2015). The infestation stage of *E. torus* on banana plant was observed as larvae. They were found feeding on the young leaves by making leaf rolls on edges of leaves. To assess the incidence of banana skipper, the observation was made twice in a month on random selected spots and the percentage of damage was estimated by counting both damaged and total number of banana plants. Banana was cultivated as an intercrop in areca nut and coconut garden (Fig. 1, 2, 3).

The life cycle of *E. torus* includes egg, larva, pupa and adult stages. Larvae were found to feed on the leaves of plants inside the leaf rolls, under the natural conditions. Each female skipper laid about

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Fig. 1 intercopping

Fig. 2 Infested banana plant with *E. torus*

Fig. 3 Banana - leaf rolls

Plate 1a. Eggs of *Erionota torus*

Plate 1b. I instar larvae of *E. torus*

Plate 1c. II instar of *E. torus*

Plate 1d. III instar larvae of *E. torus*

Plate 1e. IV instar larvae of *E. torus*

Plate 1f. V instar larvae of *E. torus*

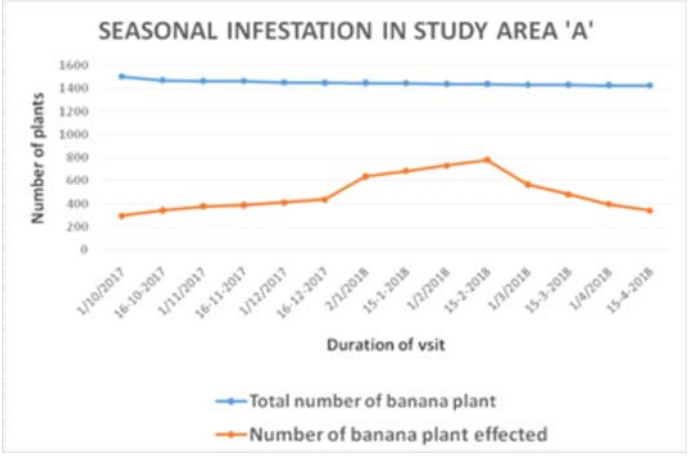

Fig. 4 Popuationof *E. torus* on banana plant during rainy, winter and summer season in Study area A

Fig. 5 Population of *E.torus*on banana plant during rainy, winter and summer season in Study area B

Plate 2c. Adult after emergence

Plate 2d. Winged adult of *E. torus*

12 to 25 eggs in batches. Larva moult four times and transform into pupa within 20 to 30 days and pupa metamorphose into adult in 12 to15 days and is brown in color. Eggs are observed under the leaf and they hatched into I instar larvae after 8 to 10 days. The young larvae feed on the tender leaves and started constructing leaf rolls on the edge of the leaves. The V instar larva transformed into pupa after 2 to 3 days depending on the temperature. The pupation occurs within the leaf rolls and it took 12 to 15 days to emerge into adults. Adults were brown in color and lived for five months and can produce five generations in a year. The life cycle of this pest completed in 55-60 days (Plate 1, 2).

Line transect method was adapted to study *E. torus* in different sites depending upon the nature of habitats. A pre-transect survey was conducted to identify and photograph *E. torus* found in the area, Agasavalli (latitude of 13.52º, longitude of 75.24º) and Mandagadde (latitude of 13.688º and 75.24 longitudes) in Shimoga district. The study was carried out during October 2017 to April 2018 and observations were recorded at fortnightly intervals.The pest incidence was observed throughout the crop period. It was observed that in the winter season maximum pest's incidence was recorded and the infestation decreased in the summer season (Fig. 4 and 5). The percentage of infestation increased from 20 to 55.23 per cent during winter season due to the prolonged life cycle of *E. torus* and it gradually decreased to 24.02 per cent in summer season (Study area A) and the percentage of infestation increased from 17.04 to

Plate 2a. V instar larva under pupation

Plate 2b. Pupa after 10 days of pupation

50.01 per cent during winter and gradually decreased to 31.05 per cent during summer season (Study area B) due to high temperature which affected the larval lifespan.

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(Received 18 August 2018; revised ms accepted 02 September 2018; published 10 October 2018)

ENTOMON 43(3): 219-222 (2018)
Short Communication No. ent. 43309

Laboratory evaluation of cashew nut shell liquid against chilli aphid *Aphis gossypii* Glover (Homoptera: Aphididae)

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ABSTRACT: The chilli aphid *Aphis gossypii* G. is one of the major sucking pests of chilli causing crinkling and yellowing of leaves. Laboratory study showed that Cashew nut shell liquid (CNSL) 0.2 % was equally effective as the chemical check, thiamethoxam 0.03 % at 24, 48 and 72 hours after treatment.

KEY WORDS: Cashew nut shell liquid, *Aphis gossypii*, management

Chilli (*Capsicum annuum* Linn.) is one of the major commercial crops and occupies the first position among the spices produced in India. Although, the crop has got great export potential, low productivity limits the full exploitation. The ravages by pests drastically reduces the chilli productivity. The sucking pest complex comprising of chilli thrips (*Scirtothrips dorsalis*), aphids (*Aphis gossypii*) and yellow mites (*Polyphagotarsonemus latus*) desap the plants causing curling, distortion and discoloration of leaves, leading to stunted growth. Both adults and nymphs of *A. gossypii* result in direct damage by sucking sap from plant parts resulting in wrinkled, yellow and stunted leaves. Indirectly it also affects the crop by excreting honeydew that favour the growth of sooty mould that inhibit photosynthesis (Singh *et al.,* 2014). Simons (1955) reported *A. gossypii* and *M. persicae* as vectors of Cucumber Mosaic Virus. Both nymphs and adults of aphids transmit pepper vein mottle virus (Alegbego, 1986). The flower buds became brittle and drop down. Severely infested plants were affected in all their growth parameters (Kumar, 1999).

The failure of insecticide control strategies coupled with the chances of leaving high pesticide residues warrants development of alternate eco-friendly management measures. Plant origin insecticides are emerging as replacements to chemical pesticides particularly in kitchen garden that are comparatively easily degradable, least toxic to natural enemies, pollinators, mammals and safer for the environment. The nut of cashew has a shell of about 1/8 inch thickness with a honey comb structure which has a high concentration of phenolic compounds like anacardic acid, cardol which are used as a defence against insect pests (Venmalar and Nagaveni, 2005). The dark reddish brown viscous liquid exuding from the shells during cashew processing known as the Cashew Nut Shell liquid (CNSL) is a by-product of cashew industry available in quantity at minimal cost.

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The efficacy of CNSL against chilli aphid under laboratory condition is being evaluated in the present investigation.

Laboratory evaluation of the botanical insecticides was done taking aphid (*A. gossypii*) as test insect. The test insects were reared on seedlings of chilli *C. annuum* variety Jwalamukhi obtained from Instructional farm, College of Agriculture, Vellayani which were planted in grow bags. Aphids were collected from the field and released into these plants and protected using cylindrical polyester cages having cloth lined ventilations. The population thus maintained served as source of aphids. The gravid females were collected from the population and transferred to new plants from which 50 numbers of second instar nymphs were collected and transferred carefully to chilli seedlings (three to four leafed stage) planted in a 150 mL cup using a camel hairbrush and used for the experiment. A white paper was kept at the base of the seedlings.

Cashew nut shell liquid (CNSL), was evaluated as emulsions at different concentrations (0.025, 0.05, 0.075, 0.1 and 0.2 %) along with Neem Seed Kernel Extract (NSKE) emulsion 5 %, neem oil emulsion 2 % and commercial botanical pesticide oxuron 5 ml l^{-1}. Thiamethoxam 0.03 % served as chemical check. The plants sprayed with distilled water served as untreated check. These seedlings with aphids were then covered with a transparent cup having pinholes. Three replications were maintained for each treatment. The number of dead aphids was counted at 24, 48 and 72 hours after treatment. The mortality of aphids treated with different botanical pesticides were corrected with mortality in untreated check using Abbot's formula and the cumulative corrected percentage mortality at 24, 48 and 72 hours after treatment (HAT) (Table 1).

Among the various treatments evaluated, the chemical check thiamethoxam 0.03%, CNSL 0.2% and neem oil emulsion 2 % recorded 66.67, 64 and 58% mortality respectively of chilli aphid and were superior to all other treatments at 24 HAT. This was followed by oxuron 5 ml l^{-1}, CNSL 0.1 %, CNSL 0.075%, NSKE 5% and CNSL 0.05% with mortality of 49.33, 47.33, 47.33, 41.33 and 42% respectively which were on par with each other.

Table1. Corrected * cumulative per cent mortality of *Aphis gossypii*treated with different botanical pesticides

Treatments	Per cent mortality**		
	24 HAT	48 HAT	72 HAT
T1 (CNSL 0.025 %)	24.67 (29.60)^{d}	80.67 (64.17)^{bc}	98.00 (83.34)
T2 (CNSL 0.05 %)	42.00 (40.39)^{c}	80.33 (64.18)^{bc}	98.67 (85.96)
T3 (CNSL 0.075 %)	47.33 (43.46)^{c}	88.67 (70.94)^{ab}	99.33 (87.09)
T4 (CNSL 0.1 %)	47.33 (43.46)^{bc}	86.00(68.44)^{abc}	100.00 (89.71)
T5 (CNSL 0.2 %)	64.00 (53.15)^{a}	92.67 (74.40)^{a}	100.00 (89.71)
T6 (NSKE 5 %)	41.33 (39.97)^{c}	76.00 (60.70)^{cd}	97.33 (82.46)
T7 (Neem oil emulsion 2 %)	58.00 (49.83)^{ab}	79.33 (63.24)^{bc}	98.00 (83.34)
T8 (Oxuron 5 ml l^{-1})	49.33 (44.61)^{bc}	85.33 (67.67)^{abc}	100.00 (89.71)
T9 (Thiamethoxam 0.03 %)	66.67 (54.73)^{a}	86.67 (69.44)^{abc}	100.00 (89.71)
CD(0.05)	8.440	9.296	NS

*Corrected with Abbot's formula over control

**Mean of 3 replications comprising 50 aphids each

(Values in the parentheses are angular transformed values); HAT: Hours After Treatment

CNSL 0.025% recorded least mortality (24.67%) after 24 hours. At 48 HAT, CNSL 0.2%, CNSL 0.075%, thiamethoxam 0.03%, CNSL 0.1% and Oxuron showed superiority over other treatments with mortality of 92.67, 88.67, 86.67, 86 and 85.33% respectively while at 72 HAT, thiamethoxam, oxuron, CNSL 0.2% and CNSL 0.1% showed 100 per cent mortality which did not vary significantly from the other treatments *viz.,* CNSL 0.075%, CNSL 0.05%, CNSL 0.025%, neem oil 2% and NSKE 5% with 99.33, 98.67, 98, 98 and 97.33% mortality respectively.

The study indicated the suitability of CNSL, mortality increased with increase in concentration and was found to be as effective as the chemical check, thiamethoxam. These were followed by the botanical pesticides, oxuron and neem oil emulsion.The pesticidal property of CNSL is attributed due to the presence of the phenolic compounds cardanol and cardol (Venmalar and Nagaveni, 2005). The toxicity of CNSL was also documented against coconut root grub (John *et al*., 2008), *Helicoverpa armigera* and *Spilarctia obliqua* (Mahapatro, 2011) at concentrations ranging from 1- 25%. In the present study, CNSL was found to have pesticidal effect against *A. gossypii* at a much lower concentrations of 0.075 to 0.2%. Olotuah and Ofuya (2010) evaluated CNSL at concentrations ranging from 0.01 to 1% against *A. craccivora* and identified that the 1% formulation was most effective. Eventhough mortality of aphids at 24 HAT was higher in CNSL 0.2%, this was found to be on par with neem oil 2% and thiamethoxam 0.03%. The mortality of aphids in the treatment with neem oil can be attributed to the presence of azadirachtin, the tetranortriterpenoid plant limonoid having insecticidal properties (Pavela, 2007). The toxicity of neem oil on the adults and nymphs of *A. gossypii* was reported earlier by Souza *et al*. (2015). Thiamethoxam which was reported as an effective insecticide against sucking pests in cotton (Nagger and Zidan, 2013), okra (Ghosh *et al.*, 2016) and green gram (Sujatha and Bharpoda, 2017) remained highly effective against *A. gossypii* also. The oxuron, a commercial botanical product comprising of neem oil and karanja oil was found to be equally effective as CNSL against *A. gossypii* at 48 HAT which was in line with the work of Arya (2015). The toxicity of neem and pungam oil was proved by several workers (Devakumar *et al.,* 1986).

ACKNOWLEDGEMENTS

The authors are thankful to Kerala Agricultural University for providing facilities for conducting the experiment as a part of M Sc. Thesis and Mahatma cashew exports, Kollam for providing Cashew Nut Shell Liquid.

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(Received 18 August 2018; revised ms accepted 22 September 2018; published 10 October 2018)

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Statement of ownership and other particulars of ENTOMON

(Form IV, Rule 8 of Registration of Newspapers (Central) Rules 1956)

1.	Place of publication	:	Trivandrum
2.	Periodicity of publication		Quarterly
3.	Printer's name, nationality and address	:	Dr K D Prathapan, Indian, Secretary, Association for Advancement of Entomology, Department of Entomology, College of Agriculture, Kerala Agricultural University, Vellayani PO, Thiruvananthapuram 695522, Kerala, India
4.	Publisher's name, nationality and address	:	- do-
5.	Editor's name, nationality and address	:	Dr M S Palaniswami, Indian, Chief Editor, ENTOMON, Association for Advancement of Entomology, Department of Entomology, College of Agriculture, Kerala Agricultural University, Vellayani PO, Thiruvananthapuram 695522, Kerala, India
6.	Name and address of the Individual who owns the paper	:	Association for Advancement of Entomology, Department of Entomology, College of Agriculture, Kerala Agricultural University, Vellayani PO, Thiruvananthapuram 695522, Kerala, India

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10 October 2018 — Publisher, ENTOMON

Association for Advancement of Entomology

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Published by :

Association for Advancement of Entomology
Department of Entomology, Kerala Agricultural University
Vellayani P.O, Thiruvananthapuram 695522, Kerala, India
Email : aae@kau.in; web: www.entomon.in

Layout and printing at SB Press, Trivandrum - 695 001