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ENTOMON

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Note from the Chief Editor

Dear Entomologists,

Warm greetings to one and all!

It is time to update you on ENTOMON.

The Association for Advancement of Entomology (AAE) functioning at the Department of Agricultural Entomology, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram, Kerala 695522 has been successful in publication of the journal ENTOMON in a time bound manner. It was plausible only with the continuous support and cooperation of research entomologists from India and abroad. The new format of ENTOMON has gained wide acceptance among the members, readers, peer reviewers and our stakeholders.

After a long gap, ENTOMON regained the National Academy of Agricultural Sciences (NAAS) score in 2015. The NAAS rating of the journal, that was 4.12 in 2015, has shot up to 4.48 in 2016. The University Grants Commission, New Delhi has recognized ENTOMON by including the journal in its approved official list of academic journals for career advancement of the faculties.

Happy to inform that ENTOMON has been included in CABI's full text repository. It was request from CABI Head Office, Oxfordshire, OX10 8DE, United Kingdom. By including the scientific papers from ENTOMON in

the repository we can ensure that they are preserved and easily located by scientists and professionals throughout the world, both now and in the future. This would also be a valuable way of promoting the journal and its research amongst the global users of both databases.

This is a moment to cherish and cheer our untiring efforts for excellence. It is appropriate to mention here that this could be achieved by the relentless and steadfastness of the office bearers who are rendering their valuable service purely on a voluntary basis.

The support of our printers, M/s SB Press, Thiruvananthapuram, is gratefully acknowledged.

Graciously presenting the first issue of ENTOMON 2017 - March (Volume 42 : 1).

Thanking the contributors, peer reviewers and institutions for the continued support.

MOTHER EARTH AWAITS - "ECOLOGICALLY VIABLE ENTOMOLOGICAL TECHNOLOGIES"

Dr M.S. Palaniswami

Chief Editor

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Dolichogenidea stantoni (Hymenoptera: Braconidae) a potential biocontrol agent for melon borer, *Diaphania indica*

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ABSTRACT: Potential of *Dolichogenidea stantoni* (Ashmead) as a biocontrol agent for the melon borer *Diaphania indica* (Saunders) was investigated during 2014-15 at field level. Influence of abiotic and biotic factors on the population dynamics of *D. indica*indicted that it was positively correlated with morning relative humidity and rainfall and was negatively correlated with evaporation, parasitism by parasitoids *D. stantoni* and *Goniozus sensorius*. Both abiotic and biotic factors collectively contributed 73.7 per cent to the variation in the *D. indica* population, in which 62.70 per cent of the fluctuation could be predicted by parasitism by *D. stantoni* alone indicating that parasitism by *D. stantoni* plays a major role in regulating the population of *D. indica.*

KEYWORDS: Bitter gourd, *Diaphania indica, biocontrol*, *Dolichogenidea stantoni*

INTRODUCTION

Bitter gourd (*Momordica charantia* L) is an important cucurbitaceous vegetable that has nutritive and medicinal values. The melon borer *Diaphania indica* (Saunders) (Lepidoptera: Pyralidae) is a potential pest of all cucurbits like, muskmelon, cucumber, gherkin, bottle gourd, bitter gourd, snake gourd and more (Ke *et al*., 1988; Peter and David, 1990; Ravi *et al*., 1997a; 1997b; 1998; Radhakrishnan and Natarajan, 2009; Pandy, 1977; Tripathi and Pandy, 1973), causing 14 - 30 *per cent* yield loss (Kulkarny, 1956; Jhala *et al.*, 2005; Singh and Naik, 2006).

The natural pest control provided by predators and parasitoids is an important ecosystem service that supports agricultural production (Losey and Vaughan, 2006). Estimation of parasitism in the field over a period of time is the foremost step in quantifying the natural mortality of pests by different natural enemies. A diverse array of natural enemies was recorded on *D. indica* worldwide. In India, 25 species of natural enemies were recorded from the *D.indica* that infested cucurbits (Peter and David, 1991a), of which the larval parasitoid *Dolichogenidea stantoni* (Ashmead) (Hymenoptera: Braconidae) was reported as a potential natural enemy (Ganga Visalakshy, 2005; Krishnamoorthy *et al.*, 2003).

Although biological control of *D. indica* represents a key strategy, its potential has gone largely unrealized in many cucurbit cropping systems throughout the world. The significant factor that disrupts biological control of arthropod pests in most

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of the cropping systems is the heavy reliance on insecticides (Stern *et al*., 1959; Croft, 1990). So if we are able to mass multiply and release the most promising natural enemy, the pesticide showers can be avoided, which is more critical in medicinally important vegetable like as bitter gourd. Hence the present study was conducted to assess the role of natural enemies and abiotic factors on the population of *D. indica* on bitter gourd and thereby identify and evaluate the potential of *D. stantoni* as an effective biological control agent for controlling *D.indica.*

MATERIALS AND METHODS

The experiment was conducted on bitter gourd (*Momordica charantia* L) plants that were raised in a staggered manner from December 2014 to December 2015 (four consecutive cropping seasons) so as to expose the all the sages of crop at any point of time line in the Indian Institute of Horticultural Research (ICAR-IIHR), Bangalore (13°58¹ N, 77°35¹ E), India. The test field consisted of bitter gourd crop (the Arka Harit variety) grown in two blocks of 50m x 20m, with a plant-to-plant spacing of 2m. These plants were not exposed to any chemical pesticide sprays and since all the plants that were being considered for the study were in one contiguous block, there were no differential natural variables (abiotic factors) influencing them.

Population dynamics of *D. indica* and its parasitoid species

The population density of *D.indica* on bitter gourd was assessed during December 2014 - December 2015 and expressed as the number of larvae per plant. From each block as mentioned above, 75 plants were randomly selected and number of larvae from each plant was recorded and collected separately. Since the plants of different age groups will have different height and canopy size, different sampling methods were adopted for bittergourd plants of different age, to ensure enough sampling size from each age group.

The bitter gourd plants were categorized into three growth stages based on the age of the host plants, *viz.*, pre-flowering stage (less than a month old plants), flowering stage (1–2 months old plants) and fruiting stage (above 2 months old plants). In the pre-flowering stage (bitter gourd plants, which were less than one meter tall), each block was sampled for a duration of 30 minutes and in the flowering stage (bitter gourd plants, which were 0.5-1.5 meter) for 1 hour. Bitter gourd plants, which were more than 1.5 meter tall, were divided into three sections (i.e. upper, middle, and lower parts) and each section was searched 30 minutes for infestation. The larvae that were found during this sampling period were collected in plastic jars with bitter gourd leaves.

A record of the parasitoids reared from the field-collected larvae was maintained and later converted to percentage parasitism. Observations on the total number of larvae collected, pupated and parasitized were also recorded from each collection, to assess the potential of different parasitoids as a mortality factor of *D. indica* during different months. This was repeated weekly for one year (2014 December–2015 December).

Carl Pearson's correlation analysis was utilized to investigate the impact of different abiotic components on the population of *D.indica*. Correlation coefficients among the pest population (number of *D.indica* larvae per plant), parasitoids (*D. stantoni*, X_8, *G. sensorius,* X_9, and *E. brevicornis,* X_{10}) and weather parameters viz., maximum temperature (X_1), minimum temperature (X_2), morning relative humidity (X_3), evening relative humidity (X_4), evaporation (X_5), wind speed (X_6) and rainfall (X_7), were computed during 2014–2015. The population densities of *D.indica* and its natural enemies as well as the weather parameters seven days before the date of observation were analyzed by using backward multiple regression analysis to find the most effective mortality factor for *D. indica* (Snedecor and Cochran, 1967). The model's adequacy was judged by computing the value of the coefficient of determination (R^2) (Draper and Smith, 1981) and statistical analysis of the data was carried out by using the SPSS software (SPSS Inc; version 21).

RESULTS AND DISCUSSION

Population dynamics of *D. indica* and its parasitoid species

The population density of *D. indica* ranged from 0.50 to 35.14 larvae per plant during the study period. The highest population density of *D. indica* was observed from June to November and the lowest from April. The population density of *D. indica* steadily increased from May and reached its peak in September. A mean infestation of 27.89 larvae per plant was recorded during the month of September. The population density of *D. indica* showed a gradual decline from December 2014 - April 2015 (6.75 - 0.88 larvae per plant). Inverse density dependence was observed between *D. indica* and *D. stantoni* during the study period (Table 1).

Three larval parasitoids - *D. stantoni*, *E. brevicornis* and *G. sensorius* - were found attacking *D. indica* during the study period. During this period, the impact of *E. brevicornis* and G. *sensorius* were negligible, whereas the parasitoid *D. stantoni* was actively prevailing throughout the study period. The percentage parasitism of *D. stantoni* ranged from 6.53 to 53.99 per cent during 2014 - 15. The parasitism as recorded in December, 2014 was 38 per cent that reached a peak of 53.99 per cent in March, 2015 and fluctuated until the next December (Table 1). Similarly, the population of *G. sensorius* and *E. brevicornis* ranged from 0.00 to 10.00 per cent and 0.00 to 4.58 per cent, respectively, during December 2014 - December 2015.

Effect of abiotic factors and biotic factors on *D. indica*

The impact of the larval parasitoids and the weather parameters, on the population of *D. indica* were assessed during 2014 - 2015 (Table 2). *D. indica* population increased during the months of maximum rainfall (r=0. 56) and humidity(r=0. 58). The population of *D. indica* was significantly and

Table 1. Abundance of *Diaphania indica* (mean number / plant) and its natural enemies (percentage parasitism) on bitter gourd during 2014-15

Months	*Diaphania indica* (Number/plant)	Percentage parasitism by *D. stantoni*	Percentage parasitism by *G. sensorius*	Percentage parasitism by*E. brevicornis*
December 14	1.58	38.00	10.00	0.00
January 15	2.32	39.53	10.00	0.00
February 15	1.92	39.31	7.50	0.00
March 15	1.00	53.99	0.00	0.00
April 15	0.88	50.00	2.75	0.00
May 15	6.01	16.55	1.00	0.00
June 15	8.31	25.25	0.00	4.58
July 15	11.17	6.53	0.00	3.10
August 15	21.93	10.53	0.00	0.00
September 15	27.89	8.11	0.00	0.00
October 15	16.92	9.00	5.00	0.00
November 15	13.34	19.18	5.00	0.00
December 15	6.75	26.96	10.00	0.00

negatively correlated with evaporation (r=-0.36) whereas no significant relationship was observed with other weather factors (Table 2). Parasitism by *D. stantoni* and *G. sensorius* had a negative significant correlation (r = -0.79, -0.36).Whereas parasitism by *E. brevicornis* couldn't establish a significant relationship with *D. indica*. The regression equation that fit with all the parasitoids and weather parameters to predict *D. indica* incidence was $Y = 22.9 - 11X_1 - 0.41X_2 + 0.26X_3 - 0.23X_4 - 0.536X_5 - 0.16X_6 + 0.39X_7 - 0.28X_8 - 0.51X_9$.

Table 2. Correlation between the *Diaphania indica* population, weather factors and parasitoids

Variable	Correlation coefficient Y (r) value
X_1 (Maximum temperature)	0.004^{NS}
X_2 (Minimum temperature)	0.210^{NS}
X_3 (Morning relative humidity)	0.582^{**}
X_4 (Evening relative humidity)	0.187^{NS}
X_5 (Evaporation)	0.357^{**}
X_6 (Wind speed)	0.025^{NS}
X_7 (Rainfall)	0.557^{**}
X_8 (Parasitism by *D. stantoni*)	0.793^{**}
X_9 (Parasitism by *G. sensorius*)	0.360^{**}
X_{10} (Parasitism by *E. brevicornis*)	0.009^{NS}

**Significant at P = 0.01
*Significant at P = 0.05

The results indicated that 73.70 per cent (R^2=0.737) of the variation present in the *D. indica* population could be predicted by abiotic factors and parasitism. To reach the optimized model 4, four variables - maximum temperature, evening relative humidity, wind speed and evaporation - were removed, which were collectively responsible for only 0.03 *per cent* of the variation. The optimized model 7 revealed the combined effect of rainfall and parasitism by *D. stantoni* on the variability in total infestation up to 69.7 per cent (R^2=0.697) during 2014 - 2015. The remaining three variables viz. *G. sensorius*, morning relative humidity and minimum temperature contributed 3.4 per cent only. The optimized model 8 revealed that *D. stantoni* alone could cause up to 62.70 per cent (R^2=0.627) variability in pest incidence and rainfall could make a contribution of 6.65 per cent (Table 3).

Abiotic and biotic factors collectively contributed about 73.7 per cent to the variation in the *D. indica* population. But the main population fluctuations (62.7 %) were due to one factor, namely, *D. stantoni*, which was the dominant parasitoid that was associated with *D.indica. E. brevicornis* and *G. sensorius* were also present but at lower levels. These findings were in agreement with that of Peter and David (1991a), who reported *Apanteles* (=*Dolichogenidea*) *taragamae* as the dominant parasitoid affecting *D. indica*.

Table 3. Regression analysis of weather factors and parasitism on *Diaphania indica*

Model type	Statistical model	R2
Full regression model	$Y = 22.9 - 11_{X1} - 0.41_{X2} + 0.26_{X3} - 0.23_{X4} - 0.536_{X5} - 0.16_{X6} + 0.39_{X7} - 0.28_{X8} - 0.51_{X9}$	0.737
Optimized model 1	$Y= 20.64 - 0.42_{X2} + 0.26_{X3} - 0.23_{X4} - 0.63_{X5} - 0.15_{X6} - 0.39_{X7} - 0.28_{X9} - 0.50_{X9}$	0.737
Optimized model 2	$Y= 20.343 - 0.46_{X2} + 0.25_{X3} - 0.21_{X4} - 0.63_{X4} + 0.40_{X7} - 0.28_{X8} - 0.47_{X9}$	0.737
Optimized model 3	$Y= 24.124 - 0.71_{X2} + 0.13_{X3} - 063_{X5} + 0.43_{X7} - 0.31_{X8} - 0.47_{X9}$	0.734
Optimized model 4	$Y=18.85 - 0.77_{X2} + 0.19_{X3} + 0.43_{X7} - 0.32_{X8}$	0.731
Optimized model 5	$Y= 30.15 - 0.60_{X2} + 0.50_{X7} - 0.36_{X8} - 0.32_{X9}$	0.719
Optimized model 6	$Y= 17.690 + 0.50_{X7} - 0.35_{X8} - 0.19_{X9}$	0.705
Optimized model 7	$Y= 17.041 + 0.54_{X8} - 0.36_{X7}$	0.697
Optimized model 8	y=20.26-0.42X8	0.627

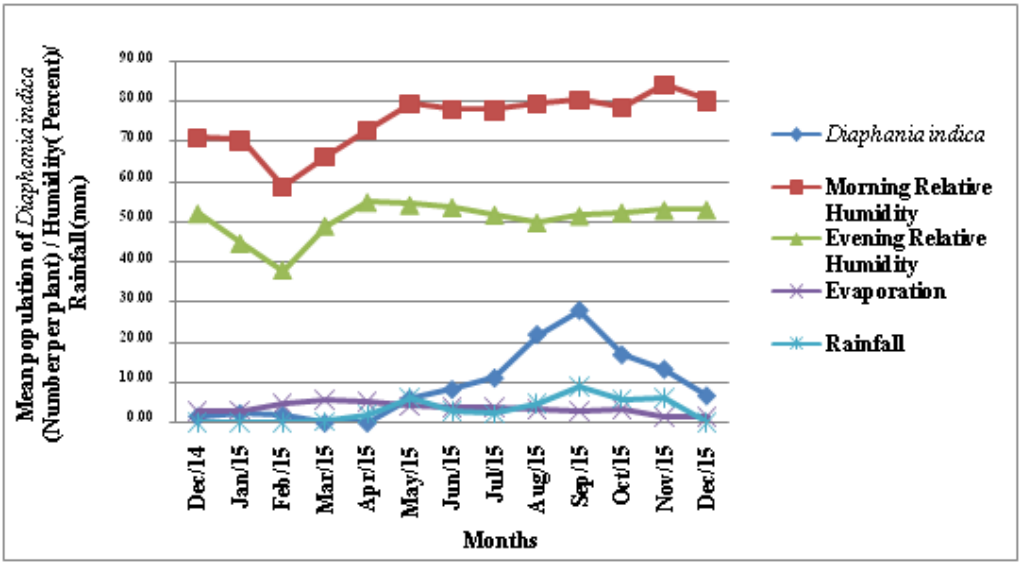

Fig. 1. Population fluctuations of *Diaphania indica* in relation to rainfall, humidity and evaporation during 2014-15

Activity of *D. stantoni* during December - April was high and could have caused a corresponding decrease in the population of *D. indica*. This is in near agreement with the findings of Peter and David (1991b), who observed the peak activity of *A. taragamae* was during October–March when the total mortality of the pest was the highest as compared to the period May–November. Therefore, it was evident that although the pest was present throughout the year, its activity was greatest from May to November, when the activity of *D. stantoni* was at its lowest. During December to April when the activity of *D. stantoni* was at its maximum, the population of *D. indica* was correspondingly reduced, suggesting a major role of this parasitoid as a mortality factor operating on *D. indica* (Fig. 1). Hence, D. *stantoni* could be used as a promising candidate for biological control of *D. indica* due to its aggregative response to host density. Additional studies on aggregation behavior, pattern of parasitism and functional response are required to explore the implications of this parasitoid on *D. indica* population.

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Occurrence of *Chrysodeixis chalcites* (Esper) (Lepidoptera: Noctuidae: Plusiinae) on soybean in Rajasthan, India

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ABSTRACT: Among the defoliator insect pests of soybean, the semiloopers and caterpillars of Noctuidae cause considerable damage that often has a significant influence on the yield. The semiloopers were active from August to October, 2015 on soybean and their population reached the peak in the 1st week of September (37th SMW) with mean population of 7.33 larvae/plant. Among the species of *Chrysodeixis*, *C. includens* and *C. chalcites* were observed, of which, *C. chalcites* has been reported infesting soybean from Rajasthan. The description of the species has been presented in the paper with suitable photographs and diagrams.

KEY WORDS: Lepidoptera, Noctuidae, *Chrysodeixis chalcites*, Soybean

INTRODUCTION

The insects included under the family Noctuidae are of universal distribution and exhibit immense variety in size, shape and coloration as imago, but are differentiated from other families by their neuration. The plants belonging to Mimosaceae, Malvaceae, Euphorbiaceae, Poaceae, Anacardiaceae, Leguminoceae, Myrtaceae, Apocynaceae, Verbenaceae, Coniferae and Moraceae are frequently infested by noctuids (Kirti and Dar, 2013). The semilooper subfamily Plusiinae was erected by Boisduval (1829) that is moderately large and taxonomically compact amongst the Noctuidae. The moths are distributed worldwide except in the Antarctic (Zahiri and Fibiger, 2008) and represented by approximately 500 species worldwide (Ronkay *et al.,* 2008). A list of 21 species under Plusiinae as part of Noctuidae is listed from India (Ronkay, 1986; 1987 and Ronkay *et al.*, 2008; 2010). Shashanka and Singh (2014) have reported 25 genera with 59 species under subfamily Plusiinae and 5 species of the genus *Chrysodeixis* from India.

Soybean is a major oilseed crop in India and is grown in the states of Madhya Pradesh, Maharashtra, Karnataka, Uttar Pradesh, Rajasthan, Tamil Nadu, Andhra Pradesh and Uttarakhand. About 275 insect species have been recorded infesting soybean in India; among these, defoliators and sap– sucking insects are the major constraints to soybean production (Raju *et al*., 2013). One of the more important semilooper pests is the twin-spot moth - *Chrysodeixis chalcites* (Esper, 1789) (Lepidoptera: Noctuidae: Plusiinae), a polyphagous and polyvoltine insect species that feeds on more than 30 different plant species, including fodder crops, vegetables, fruit trees and ornamental plants in the field and greenhouse. It is native to the Mediterranean and tropical regions (Rashid *et al*.,

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1971; Murillo *et al*., 2013). This insect is a serious pest of greenhouses crops in Europe (Cabello *et al*., 1996; Vanoers *et al.*, 2004). It has been reported in India from Ludhiana (Punjab) on sunflower (Singh and Singh, 1998; Singh *et al*., 2003); Bangalore (Karnataka) on ornamental plants (Narayanan, 2003); Jabalpur (Madhya Pradesh) in light trap collections (Verma and Vaishampayan, 1983) and also reported on NBAIR, database, crop pest index (Soybean); however, there are no records of damage to soybean by this pest from Rajasthan.

MATERIALS AND METHODS

A field experiment on Bio-ecological Management of Major Insect Pests of Soybean was undertaken at the Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur during *kharif*, 2015. Soybean variety JS-335, recommended for the zone, was sown in plots of size 4m x 3m maintaining 30 cm row to row and 10 cm plant to plant spacing and replicated six times. The populations of major insect pests including semiloopers were recorded from five randomly selected and tagged plants in each replication. The semiloopers were dislodged from the plants by gently shaking and collected on a white sheet kept underneath the plant. All the observations were taken during early hours of the day (6 to 8 am) on a weekly basis. The prevailing abiotic conditions of the atmosphere were recorded from the meteorological observatory of the farm to work out the correlation coefficients between the pest populations and the abiotic factors of the environment (Gomez and Gomez, 2010).

Field collected healthy larvae of the semiloopers were individually reared in glass containers (500ml capacity) in the laboratory to obtain adult moths for which fresh leaves of soybean from the field were provided daily till the larvae entered into the pupal stage. A two centimeter layer of sterilized sand was provided for proper pupation. Adults of different species of semiloopers emerged *viz*., *Trichoplusia ni* (Hubner) including species of the genus *Chrysodeixis*.

Male and female genitalic dissections were prepared following Clarke (1941). All slide preparations were examined under the stereozoom binoculars. Wing length measurements were taken from the center of the auxiliary area to the apex of the forewing. Digital photographs of specimens and their body parts were taken with the help of Stemi 2000 C Stereozoom Binoculars of Carl Zeiss make. The software installed in the binoculars used for linear measurements was Axio Vision L.E. 4.8; besides, the graph paper method was also employed. The identification of specimens was carried out using the key of Olivares (1992), Passoa (1995), Passoa (2009) and Kirti and Dar (2013). Taxonomic glossary of genitalia in lepidopteran insects (Klots, 1970) was also used.

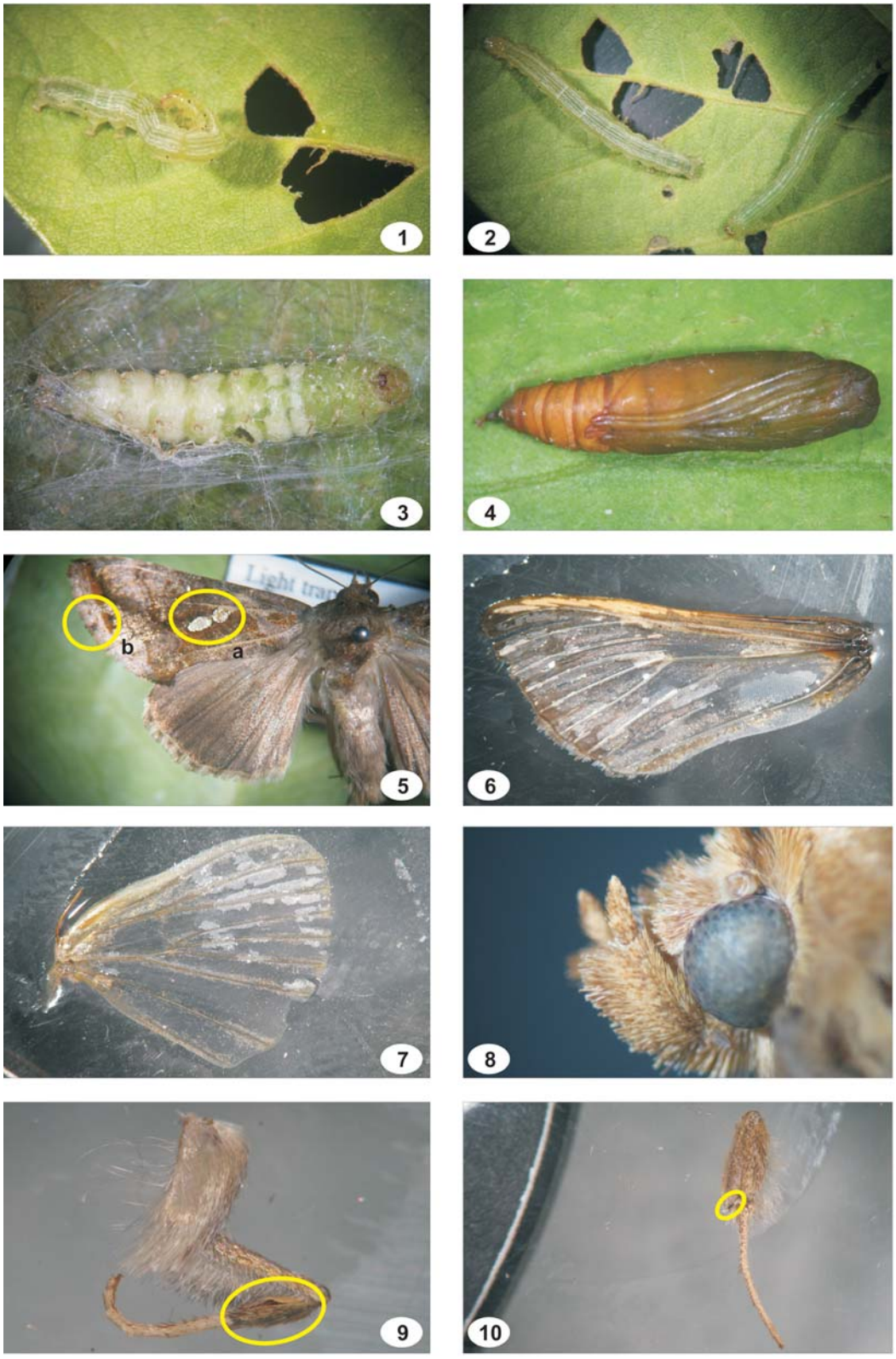
RESULTS AND DISCUSSION

Incidence of semiloopers in soybean

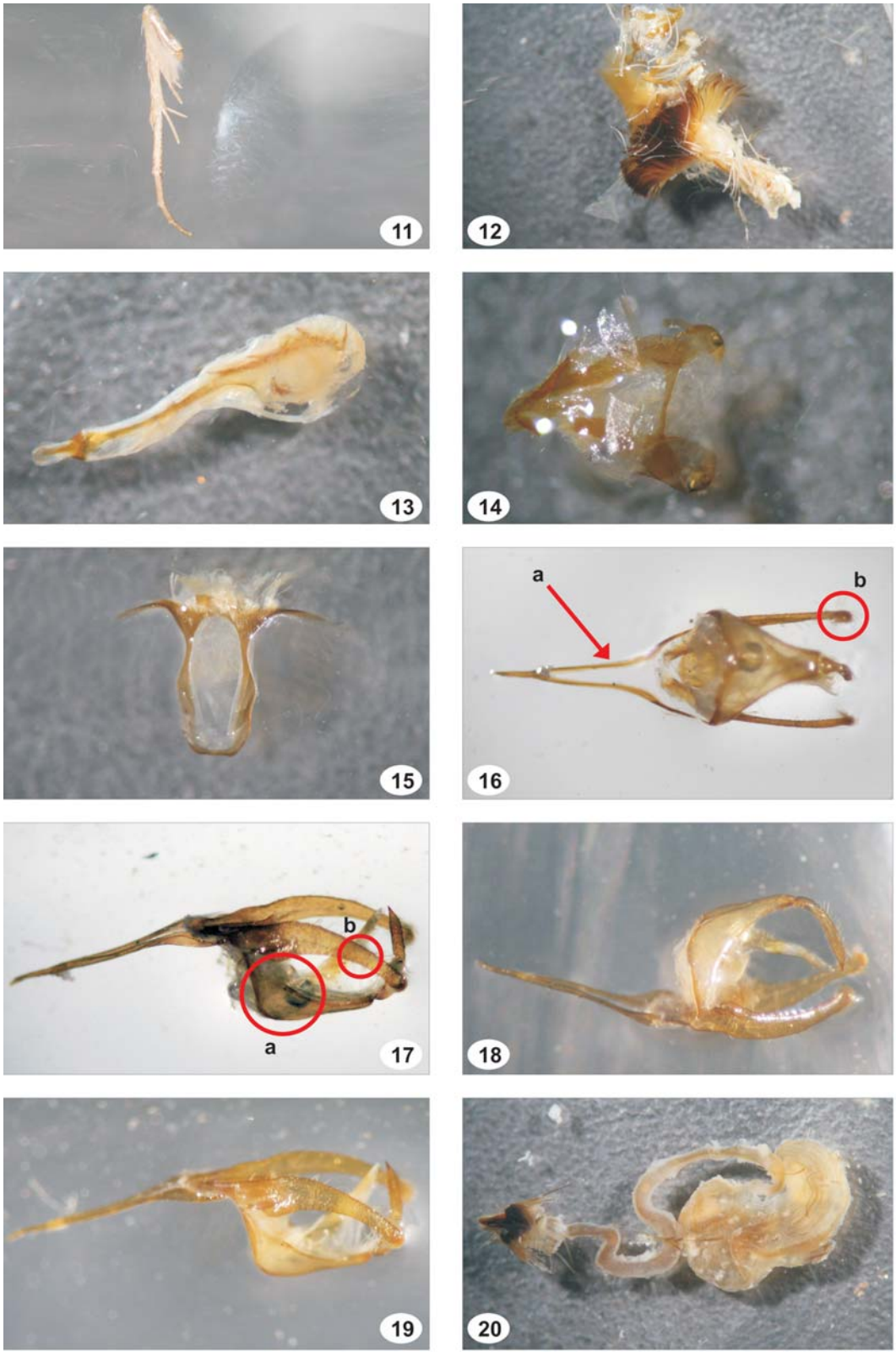
The semiloopers were active from August to October, 2015 on soybean and, as presented in Table (1), the larval numbers were significant from 1st week of August (33th SMW) with mean population of 1.67 larvae/plant. The population increased gradually and reached the peak in the 1st week of September (37th SMW) with mean population of 7.33 larvae/plant. At the peak period of activity, the mean atmospheric temperature was 26.48^{o} C, the mean relative humidity 67.14 per cent and there was no rainfall during three to four weeks; thereafter, the population declined gradually and reached to a minimum level of 0.33 larvae/plant during 2nd week of October (42nd SMW). The occurrence of *C. chalcites* on soybean has been reported from Spain (Avidov and Harpaz 1969; Amate *et al*. 1998); Zimbabwe (Taylor 1980) and in northern Italy (Zandigiacomo1990). Rashid *et al*. (1971) and Harakly and Farag (1975) observed the maximum population of *C. chalcites* larvae from August to October on tomato at the optimal temperature of 25°C.

Chrysodeixis chalcites (Esper, 1789)

Materials examined (6 Specimens, 4 ♂ & 2 ♀): India: Rajasthan, Udaipur; 2.VIII.2015, Coll. A. K. Meena (RCA, Udaipur); 8. IX. 2015, Coll. A. K. Meena (RCA, Udaipur); 7. X. 2015, Coll. A. K.



PLATE–I: ***Chrysodeixis chalcites*** **(Esper) Male 1-10: 2. Field incidence; 3. Pre-pupa; 4. Pupa; 5. Adult; 6. Fore wing details; 7. Hind wing; 8. Labial palpi; 9. Foreleg; 10. Middle leg (Spurs)**



PLATE–II: ***Chrysodeixis chalcites*** **(Esper) Male 11-20: 11. Hind leg; 12. Genitalia; 13. Aedeagus; 14-15. Sclerites of modified abdominal segment VIII; 16-19. Genitalia; 16. Dorsal view; 17. Lateral view; 20. Female genitalia**

Table 1. Seasonal incidence of semiloopers in soybean during *kharif*, 2015

SMW	Mean		Total Rainfall (mm)	Semilooper (Larvae/ plant)
	Atm. Temp. (° C)	RH (%)		
33	27.11	71.07	0	1.67
34	27.26	83.07	14.10	2.00
35	26.93	75.43	1	2.33
36	27.10	69.79	0	5.67
37	26.48	67.14	0	7.33
38	26.74	61.14	0	6.00
39	29.70	60.79	3.50	5.67
40	24.84	76.86	2.40	2.33
41	25.94	48.36	0	1.67
42	26.91	44.79	0	0.33
Coefficient of correlation (r) between population and Atm. Temp.				0.29
Coefficient of correlation (r) between population and RH				0.11
Coefficient of correlation (r) between population and Total Rainfall				-0.18

Meena (RCA, Udaipur); 9. X. 2015, Coll. A. K. Meena (RCA, Udaipur) (1); 11. X. 2015, Coll. A. K. Meena (RCA, Udaipur).

Description (Plate - I and II):

Early instar larvae are leaf skeletonizers, as they eat only a portion of the leaf to form an irregular network of minute clear areas. Later instars eat the entire leaf, at most leaving the midrib, or other veins (Fig.1, 2); the mature larvae stop feeding and enter a prepupal stage on soybean leaves and later they pupated in the soil provided (Fig. 3, 4). The thorax and/or abdomen of the adult moth have tuft of scales; they rest with the wings folded over their back in a tent like arrangement.

Forewing: The forewings are with a silver marking often shapes like a " Y, V, solid dot or boot." which are oval and sub equal in size (Fig. 5 a). A few specimens may show a bronze-colored forewing, but the twin spots are always present. On the forewing, a small black dot near the margin of the wing on vein M_2 (sometimes rubbed off) can be seen (Fig. 5 b).

Hindwing: hind wing ground color brown-gray, darker towards the margin, with dark gray veins and a pale-tan short fringe.

The key taxonomic character of Noctuidae venation of the hind wings, where Sc + R_1 is separated from R_s and is connected with discal cell at the base, has been shown (Fig. 7). Front and hind wing dissimilar in venation (Fig. 6-7). The labial palpi are of moderate dimensions, more or less upturned, with the second segment densely scaled, the third generally short; and eyes without hairs (Fig. 8). Another identifying feature is number of tibial spurs i.e. 0-2-4 (foreleg-midleleg-hindleg) and epiphysis present in foreleg (Fig. 9-11).

Male genitalia: The soybean semiloopers are often confused although the male genitalia are very different. Male of *C. chalcites* have tufts of pale long scales on the sides of the abdomen and black long scales on the apex, genitalia and abdominal segment VIII, ventral (Fig. 12). Aedeagus with cornuti, elongated and its posterior apex globose, three times than the rest (Fig. 13). Sclerites from modified abdominal segment VIII, with black scales removed (Fig. 14-15). Genitalia, dorsal view, saccus elongated sub equal in length to the valve and V shaped, apex more acute (Fig. 16-19); saccus longer than valva (Fig. 16, a). The genitalia are characterized by valva without claspers or claves, valva (Lateral view, Fig. 17, b) elongate and wider at base than towards the apex, with tight groups of setae at the apical margin (Fig. 16, b); tegumen oval with lateral arms triangle-like in shape (Fig. 17, a). Uncus elongated, basal third curved; apex straight with a curved, dark spine (Lateral view of genitalia, Fig. 18-19).

Female genitalia: No differences in the constant features were observed in the female genitalia among the species. The bursa copulatrix usually lacks a well defined signum but is often generally scobinate (Fig. 20 General view of female genitalia).

Measurements: Wing expansion 40 ♂, 41 ♀ mm, the forewing length is 17 ♂ and 17.5 ♀ mm in moth.

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Insect species diversity and abundance in oak forest of Kumaun Himalaya, Uttarakhand

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ABSTRACT: Species richness, abundance and biomass, species diversity, secondary production and herbivore of insects in an oak forest of Kumaun Himalayan were studied during August 2013 to July 2015. A total of 90 species of insects belonging to 32 families under 8 orders were collected. Herbivores were dominant in terms of number of species (68.4%) and number of individuals (76.9%). Shannon-Wiener diversity index H' varied from 0 to 0.3 and Evenness (E) varied from 0 to 0.04. Mean secondary net production of herbivores was 0.638 KJ $m^2 yr^{-1}$. As a proportion of net primary production, secondary production was only 0.033% suggesting that herbivores were not food limited of the 90 species of insects collected.

KEYWORDS: Insect diversity, abundance, secondary net production, oak forest

INTRODUCTION

The Himalaya represents one of the youngest but most complex mountain systems of the world. Forests are universally known to be critically important habitats in terms of biological diversity they contain and in terms of ecological functions such as pollination, herbivore, decomposition and nutrient cycling, predatory/ parasitism of other species (Bond, 1994) and are greatly affected by relentless habitat destruction (Lowman,1997), they provide. Species richness, abundance and diversity of insects in different forest habitats have been intensively studied by many workers (Singh *et al*., 2010; Sarasija *et al*., 2012; Pande, 2013; Bhardwaj and Thakur, 2015; Usha and John, 2015). The present investigation was aimed at understanding certain structural and functional aspects of an oak forest community in Kumaun Himalaya including species richness, abundance and biomass, species and trophic level diversity, secondary net production and role of insects as pollinators in an oak forest during August 2013 to July 2015.

MATERIALS AND METHODS

The study site Naina Devi Himalayan Bird Conservation Reserve is located at Kilbury (29° 39 'N and 79° 44'E longitude; altitude 2528m) about 13 km from Nainital. The area studied is approximately 2 ha and is dominated by *Quercus leucotrichophora* A. Camus, *Q. floribunda* Lindl., *Q. semecarpifolia* Smith, *Q. lanuginosa* D. Don *and Q. glauca* Thunb. tree species. Temperature ranged from 4.6°C to 25.7°C (June). Maximum rainfall (69.2%) is during the months of July to September. On this basis, the year can be divided into three seasons namely, rainy (July to October), winter (November to February) and summer (March to June).

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Sampling of insects was done at an interval of 30 days. The insects were collected by sweep sampling method (Gadagkar *et al*., 1990) and hand-picking (Jonathan, 1990). The collected insects were killed in jars containing ethyl acetate and were oven-dried to constant weight (60^0C for 24 h). Each dried specimen was weighed in a single pan electric balance (0.01 mg accuracy) for biomass estimation. The collected insects were identified at Forest Research Institute, Dehradun.

Species diversity H' (S) was calculated using Shannon-Wiener expression (1963):

$$H'(S) = -\sum_{i=1} pi \log pi$$

Where $P_{i} = n_i/N$; n_i is the number of species present in the season ; and N is the number of individuals, S denotes the number of seasons.

Buzas and Gibson's Evenness (E_2) was calculated using:

$$E2 = e^{H/S}$$

Where, S is the number of taxa and H is the Shannon Index.

Secondary production comprises that portion of energy which is assimilated by the consumer and is transferred into organic matter, useful as source of energy for other organisms in ecosystem. Time series biomass data was analyzed using Wiegert's (1965) equation for the estimation of secondary production:

$$P = S + \sum_{i=2}^{n} \frac{(Ni + Ni - 1)}{2} (Wi - Wi - 1)$$

Where,

Ni = Number of insect present at time 1,

Wi = Mean weight per insect at time 1,

i = Sampling time (Date)

S = Standing crop at time when i = 1

It was assumed that Ni ≤ Ni-1 and Wi ≥ Wi-1. However, when Wi was less than Wi-1, the production was considered to be zero.

RESULTS AND DISCUSSION

Floristic composition: A total of 58 species were recorded in the oak forest of these, 41 species were shrubs and herbs 17 were tree species. Dominant oak species were *Quercus leucotrichopha, Q. floribunda, Q. semecarpifolia, Q. glauca and Q. lanuginosa.* Primary production of shrubs and herbs was 87.6 g m^2 yr^{-1} (Rawat, 1999).

Species richness and trophic components: A total of 90 species were collected of which 80 species were recorded in both years (Table1). Species richness was highest during summer and rainy seasons (Table 2). Species richness was positively correlated with maximum temperature (r=0.904; Pd"0.01, df=12), minimum temperature (r=0.91; Pd"0.01, df=12) and rainfall (r= 0.489; Pd"0.05, df=12). On the basis of number of species collected, 68.4% were herbivore, 20% predators, 4.7% omnivores, 4.5% parasites, 2.4% saprophages, and on the basis of number of individuals, 76.9% were herbivores, 15.3% predators, 3.3% omnivores, 2.6% parasites and 1.9% saprophages.

Gadagkar *et al*. (1990), Moran *et al*. (1994), Arya (2005) and Pande (2013) have reported that herbivores were the dominant insect group in comparisons to other trophic levels in different forest ecosystems. Herbivores in all reported habitats and in the present investigation are not limited by availability of food, and can thus maintain relatively higher abundances, whereas predatory, parasitic and other trophic components of insect communities depend considerably on the existence of refuge habitats. Thus, population or species in all trophic levels are not limited by the abundance of food and by competition for food resources (Sinclair, 1975; Belovsky, 1986).

Abundance and biomass: Abundance of insects ranged from 0 (December) to 89 ind.ha^{-1} (April) (Table 3). Abundance of insects was positively

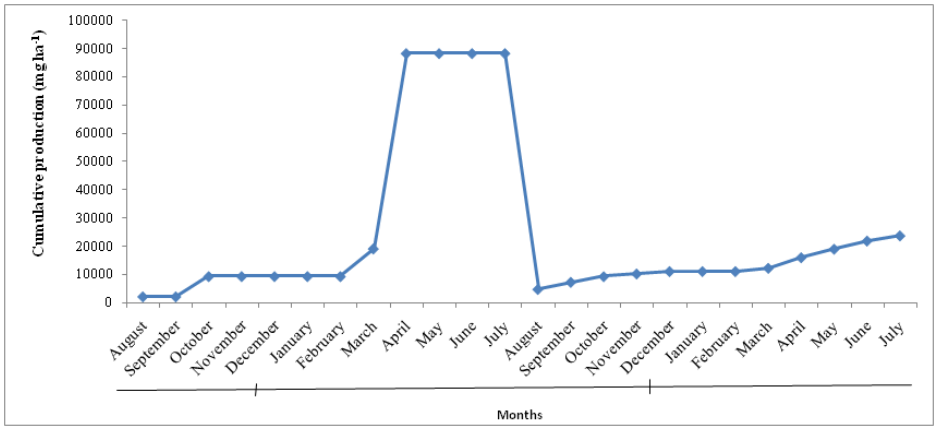

Fig. 1. Cumulative net secondary production of herbivores in oak forest during 2013-2015

Table 1. Species composition, trophic components, number of individuals and their percent contribution in the oak forest during August, 2013 - July, 2015

S. No.	Taxonomic composition	Trophic level	2013-2014		2014-2015	
			No. of individuals	%	No. of individuals	%
	ORDER- LEPIDOPTERA Family-Danaidae					
1.	*Euploea core core* Cramer	Herbivore	2	0.6	4	0.7
2.	*Danaus chrysippus* Linnaeus	,,	2	0.6	2	0.4
	Family-Nymphalidae					
3.	*Lasimmata schakra* Kollar	Herbivore	12	3.5	17	3.1
4.	*Vanessa cashmirensis* Kollar	,,	17	5.0	25	4.5
5.	*Vanessa indica* Herbrt	,,	3	0.9	3	0.5
6.	*Junonia lemonias* Linneaus	,,	1	0.3	2	0.4
7.	*Neptis yerburyi yerburyi* Butler	,,	1	0.3	3	0.5
8.	*Neptis m. mahendra* Moore	,,	4	1.2	6	1.0
9.	*Callerebia nirmala* Moore	,,	14	4.1	18	3.3
10.	*Vanessa cardui* Linnaeus	,,	1	0.3	2	0.4
11.	*Aulocera swaha* Kollar	,,	9	2.6	10	1.8
12.	*Ariadne m.cramer* Cramer	,,	1	0.3	3	0.5
13.	*Lethe verma sintica* Kollar	,,	2	0.6	2	0.4
14.	*Lethe rohria* Fabricius	,,	2	0.6	2	0.4
15.	*Junonia orithya* Linnaeus	,,	1	0.3	2	0.4
16.	*Junonia hierta* Hubner	,,	1	0.3	2	0.4
17.	*Euthalia patala* Kollar	,,	5	1.4	9	1.6
18.	*Phalanta phalantha* Drury	,,	1	0.3	2	0.4
19.	*Euthalia lubentina* Cramer	,,	-	-	6	1.0
	Family-Papilionidae					
20.	*Papilio protenor romulus* Cramer	Herbivore	2	0.6	3	0.5
21.	*Atrophaneura polyeuctes* Doubleday	,,	2	0.6	4	0.7
22.	*Papilio memnon agenor* Linnaeus	,,	1	0.3	2	0.4

S. No.	Taxonomic composition	Trophic level	2013-2014		2014-2015	
			No. of individuals	%	No. of individuals	%
	Family-Pieridae					
23.	*Pieris canidia* Evans	Herbivore	56	16.5	68	12.3
24.	*Catopsilia pyranthe* Linnaeus	,,	3	0.9	7	1.3
25.	*Aporia aganthon.caphusa* Moore	,,	2	0.6	3	0.5
26.	*Colias electo fieldi* Menestries	,,	4	1.2	5	0.9
27.	*Pontia daplidice* Linnaeus	,,	1	0.3	3	0.5
28.	*Eurema herla laeta* Boisduval	,,	5	1.4	7	1.3
29.	*Eurema hecabe* Linnaeus	,,	2	0.6	3	0.5
30.	*Gonepteryx r.nepalensis* Linnaeus	,,	-	-	2	0.4
31.	*Cepora nerissa* Fabricius	,,	3	0.9	6	1.0
	Family-Lycanidae					
32.	*Heliophorous sena* Kollar	Herbivore	9	2.6	20	3.6
33.	*Heliophorous oda* Hewitson	,,	7	2.0	11	1.9
34.	*Lycaena phlaeas* Linnaeus	,,	2	0.6	3	0.5
35.	*Zizeeria* sp.	,,	2	0.6	5	0.9
	Family-Geometridae					
36.	*Rhodostrophia sp.* Moore	Herbivore	-	-	2	0.4
	Family-Riodinidae					
37.	*Dodona durga* Kollar	Herbivore	7	2.0	4	0.7
	Family-Acraeidae					
38.	*Acraea vesta* Fabricius	Herbivore	-	-	2	0.4
	ORDER-COLEOPTERA Family-Coccinellidae					
39.	*Coccinella septumpunctata* Linnaeus	Predator	18	5.2	19	3.4
40.	*Epilachna viginitioctopunctata* Fab.	,,	2	0.6	4	0.7
41.	*Palaeoneda auriculata* Mulsant	,,	2	0.6	6	1.0
42.	*Micraspis univittata* Hope	,,	1	0.3	3	0.5
43.	*Psyllobora bisoctonotata* Mulsant	,,	1	0.3	2	0.4
44.	*Adonia variegate* Goeze	,,	1	0.3	4	0.7
	Family-Chrysomelidae					
45.	*Aulacophora foveicollis* Lucas	Herbivore	1	0.3	3	0.5
46.	*Haltica cyanea* Weber	,,	2	0.6	5	0.9
47.	*Zygogramma bicolorata* Pallister	,,	1	0.3	3	0.5
48.	*Merista quadrifasciata* Hope	,,	4	1.2	7	1.3
49.	*Altica* sp.	,,	16	4.7	31	5.6
	Family-Carabidae					
50.	*Chlaenius* sp.	Predator	2	0.6	4	0.7
	Family-Scarabaeidae					
51.	*Onitis philemon* Fabricius	Saprophagous	1	0.3	4	0.7
52.	*Oxycentonia versicolor* Fabricius	Herbivore	3	0.9	3	0.5
53.	*Anomala dimidiate* Hope	Herbivore	3	0.9	6	1.0

S. No.	Taxonomic composition	Trophic level	2013-2014		2014-2015	
			No. of individuals	%	No. of individuals	%
	Family-Tenebrionidae					
54.	*Lagria* sp.	Omnivorous	3	0.9	5	0.9
	Family-Meloidae					
55.	*Mylabris cichorri* Linnaeus.	Predator	10	2.9	12	2.2
	Family- Cerambycidae					
56.	*Lamiinae* sp.	Herbivore	-	-	1	0.2
	ORDER-HYMENOPTERA Family-Apidae					
57.	*Apis dorsata* Fabricius	Herbivore	5	1.4	7	1.3
58.	*Bombus* sp. Latreille	,,	4	1.2	4	0.7
59.	*Apis* sp.	,,	2	0.6	2	0.4
60.	*Xylocopa* sp.	,,	2	0.6	7	1.3
	Family-Vespidae					
61.	*Vespa cincta* De Geer	Predator	1	0.3	3	0.5
62.	*Vespa ducalis* Smith	Omnivorous	2	0.6	6	1.0
63.	*Polistes* sp.	Predator	-	-	5	0.9
64.	*Eumenes dimidiatipennis* De Saussure	,,	2	0.6	3	0.5
	Family-Formicidae					
65.	*Componotus compressus* Fabricius	Predator	3	0.9	4	0.7
	Family-Ichneumonidae					
66.	*chenumon xanthorious* Forster	Parasite	4	1.2	5	0.9
67.	*Xanthopimpla* sp.	,,	-	-	2	0.4
68.	*Microphthalmia bucephala* Fall.	,,	2	0.6	4	0.7
69.	*Xanthopimpla stemmator* Thunberg	,,	-	-	4	0.7
	Family-Sphecidae					
70.	*Trypoxylon* sp.	Predator	1	0.3	4	0.7
	ORDER-ORTHOPTERA Family-Gryllidae					
71.	*Gryllus* sp.	Omnivorous	5	1.4	5	0.9
72.	*Brachytrupes orientalis* Burmeister	,,	1	0.3	3	*0.5*
	Family-Acrididae					
73.	*P. scabra* Klug	Herbivore	4	1.2	8	1.4
74.	*Phlaeoba* sp.	,,	2	0.6	6	1.0
	Family- Tettigonidae					
75.	*Elimaea* sp.	Herbivore	4	1.2	5	0.9
76.	*Neoconocephalus* sp.	,,	1	0.3	3	0.5
	ORDER-HEMIPTERA Family-Pyrrhocoridae					
77.	*Physoptata gutta* Brum	Herbivore	9	2.6	13	2.4
	Family-Pentatomidae					
78.	*Dolycoris indicus* Stal	Herbivore	2	0.6	4	0.7
79.	*Palomena spinosa* Distant	,,	3	0.9	6	1.0
80.	*Murgantia histrionic* Hahn	,,	6	1.7	8	1.4
81.	*Andrallus spinidens* Fabricius	,,	1	0.3	3	0.5

S. No.	Taxonomic composition	Trophic level	2013-2014		2014-2015	
			No. of individuals	%	No. of individuals	%
	Family-Coreidae					
82.	*Euthochtha galeator* Fabricius	Herbivore	2	0.6	4	0.7
	ORDER-DIPTERAFamily-Asilidae					
83.	*Neoitamus grandis* Ricardo	Predator	1	0.3	1	0.1
84.	*Philodicus femoralis* Ricardo	,,	4	1.2	5	0.9
	Family-Tipulidae					
85.	*Tipula* sp.	Herbivore	-	-	2	0.3
	Family-Tabanidae					
86.	*Tabanus* sp.	Parasite	1	0.3	2	0.3
	Family-Muscidae					
87	*Musca* sp.	Saprophagous	5	1.4	7	1.3
	ORDER-ODONATA					
	Family- Libelluidae					
88.	*Pantala flavescence* Fabricius	Predator	1	0.3	2	0.3
89.	*P. s. sexmaculatata* Fabricius	,,	-	-	2	0.3
	ORDER -MANTODEA					
	Family-Mantidae					
90.	*Mantis* sp.	Predator	2	0.6	2	0.3
		340	100	553	100	

Table 2. Monthly variation in the species content of different taxa, total species and percentage in the oak forest during August, 2013 to July, 2015 (mean of two years)

Taxon/ Months	Lepidoptera		Orthoptera		Coleoptera		Hymeno-ptera		Odonata		Hemiptera		Diptera		Mantodea		Total
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	%
August	12	38.7	5	16.1	7	22.6	3	9.7	1	3.2	2	6.5	1	3.2	-	-	100
September	10	40.0	4	16.0	5	20.0	2	8.0	1	4.0	1	4.0	2	8.0	-	-	100
October	10	47.6	3	14.3	4	19.0	1	4.8	-	-	2	9.5	1	4.8	-	-	100
November	4	50	-	-	3	37.5	-	-	1	12.5	-	-	-	-	-	-	100
December	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
January	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
February	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
March	8	66.6	-	-	2	16.6	1	8.4	-	-	1	8.4	-	-	-	-	100
April	17	53.1	2	6.3	6	18.7	4	12.5	-	-	2	6.3	1	3.1	-	-	100
May	15	48.3	2	6.4	6	19.5	3	9.6	-	-	2	6.5	2	6.5	1	3.2	100
June	13	43.4	2	6.8	9	30.0	2	6.6	-	-	1	3.3	2	6.6	1	3.3	100
July	10	38.5	2	7.7	9	34.7	2	7.7	1	3.8	1	3.8	1	7.7	-	-	100

Table 3. Shannon-Wiener diversity index (H') and Evenness (E) of insect fauna in the oak forest during August, 2013- July, 2015

Months	August, 2013- July, 2014				August, 2014- July, 2015			
	S (Richness)	N (Abundance)	H' (Shannon index)	E (Evenness)	S (Richness)	N (Abundance)	H' (Shannon index)	E (Evenness)
August	24	38	0.24	0.01	27	76	0.30	0.01
September	22	36	0.23	0.01	23	67	0.24	0.01
October	17	32	0.22	0.01	17	44	0.23	0.01
November	6	12	0.11	0.02	6	19	0.15	0.03
December	0	0	0	0	2	8	0.08	0.04
January	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0
March	8	29	0.20	0.03	11	42	0.20	0.02
April	28	58	0.30	0.01	21	89	0.27	0.01
May	23	52	0.28	0.01	23	82	0.25	0.01
June	21	44	0.26	0.01	20	77	0.24	0.01
July	21	39	0.24	0.01	18	49	0.21	0.01
Total	**170**	**340**	**2.08**	**0.12**	**168**	**553**	**2.17**	**0.16**

Table 4. Shannon-Wiener diversity index (H') and Evenness (E) of herbivores in the oak forest during August, 2013 to July 2015

Months	August, 2013- July, 2014				August, 2014- July, 2015			
	S (Richness)	N (Abundance)	H' (Shannon index)	E (Evenness)	S (Richness)	N (Abundance)	H' (Shannon index)	E (Evenness)
August	9	28	0.28	0.03	10	47	0.25	0.03
September	8	17	0.21	0.03	8	36	0.22	0.03
October	9	25	0.26	0.03	7	21	0.17	0.02
November	3	9	0.14	0.05	3	9	0.11	0.04
December	0	0	0	0	2	8	0.10	0.05
January	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0
March	4	16	0.21	0.05	6	19	0.23	0.04
April	13	37	0.32	0.02	9	44	0.25	0.03
May	8	20	0.23	0.03	13	37	0.29	0.02
June	6	18	0.22	0.04	11	36	0.27	0.02
July	6	17	0.21	0.04	9	23	0.26	0.03
Total	**66**	**187**	**2.08**	**0.32**	**78**	**280**	**2.15**	**0.31**

correlated with maximum temperature (r=0.84; Pd"0.01, df=12), minimum temperature (r=0.832; Pd"0.01, df=12) and rainfall (r=0.42; P<<0.05, df=12). Low and high temperature and rainfall influenced the abundance of insects in the present study. Extremely low and high temperature, rainfall and vegetation cover have been reported to influence the population density of insects (Thomas *et al*., 1998; Zheng *et al*., 2008; Dev *et al*., 2009; Regniere *et al*., 2012). Biomass of insects ranged from 0 (December) to 6385.1 mg ha^{-1} (May). Biomass of insects was significantly and positively correlated with maximum temperature (r=0.786; Pd"0.01, df=12), minimum temperature (r=0.419; P<<0.05, df=12) and abundance (r=0.966; Pd"0.01, df=12).

Species diversity and Evenness: The Shannon-Wiener diversity index H' varied from 0 to 0.3 (Table 3). Herbivores had almost similar species diversity (0 to 0.32) because of their higher percent contribution towards total abundance (Table 4). Buzas's Evenness (E) which takes into account the distribution of species and their numbers across gradients have returned low values between 0 to 0.04 during the study period (Tables 3 and 4). Monthly fluctuations recorded could be due to changes in the numerical importance of some of the species. Diversity index (H') and Evenness (E) were zero during the months of December to February when insects were not recorded due to extreme cold climatic conditions.

Low species diversity index H' (0.3) recorded in the present study in comparison to reported values of 1.38 to 3.57 in different forest ecosystems (Torchote *et al*., 2010; Pande, 2013; Arya *et al*., 2015; Bhardwaj and Thakur, 2015 ; Usha and John, 2015) could be due to lower number of species and abundance of insects collected. Human disturbances such as grazing (You and Li, 2006), predatory insects (Boiteau, 1983) and cutting of vegetation (Morris and Plant, 1983) result in serious degeneration of the environment and reduction in the species diversity in different ecosystems.

Secondary net production: The tissue production estimates of herbivores in the present study is the present study is based on the calculations of the mean biomass of herbivores on each sampling data during 2013-2015 (Fig. 1). Cumulative net secondary production was 422.814 g ha^{-1} yr^{-1} (9301.9 KJ $ha^{-1}yr^{-1}$ or 0.93019 KJ m^{-2} yr^{-1}) in the first year when converted to Joules by multiplying with 22 J mg^{-1} (Kaushal and Joshi, 1991), 157.064g ha^{-1} yr^{-1}(3455.4 KJ $ha^{-1}yr^{-1}$ or 0.34554 KJ $m^{-2}yr^{-1}$) (Fig. 1). As a proportion of net primary production, secondary production of 0.033% recorded in the present study fall in the range of reported values of 0.006 to 5.8 % (Blummer and Diemer, 1996; Dev *et al*., 2009).

Insects as pollinators: Of the 90 species recorded, 61 pollinator species were observed to have visited flowers of different plants and trees regularly. Pollinator species belonged to Lepidoptera (40 species), Hymenoptera (9 species) and Coleoptera (12 species). Pollinators are essential for survival of forest ecosystems and strongly influence ecological interactions, floral diversity and genetic variation in the plants community. Although 80% the insect pollination is performed by Hymenoptera, bees in particular (Sihag, 1988; Taha and Bayoumi, 2009; Joshi and Joshi, 2010) but also by Lepidoptera (Hodges *et al*., 2002), Coleoptera (Pande, 2013) and Diptera (Larson *et al*., 2001). Pollinators recorded in the present study could also thus fulfill ecological functions such as pollination and plant-insect interactions.

The present study reveals the species richness and abundance of insects. Herbivores were the dominant group because they were not limited by the availability of food. Low species Diversity (H') and Evenness (E) could be attributed to low species richness and abundance of insects. Natural habitat conservation is very important for the existence of insect species.

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Melissopalynological investigations of *Apis mellifera* L. corbicular pollen and honey from Hisar, Haryana

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ABSTRACT: The melissopalynological analysis of corbicular pollen and honey samples collected from a single apiary of *Apis mellifera* L**.** revealed a total of 28 pollen types representing 25 genera and 19 families and a total of 26 pollen types representing 23 genera and 18 families, respectively. Only one pollen type failed to be identified while two were identified to the level of family. The observed pollen types were classified as predominant, secondary, important minor and minor pollen types. When one floral type represented is 45%, it was classified as unifloral. Of the total honey samples analyzed, January, February, March, April, June, July, October and December month samples were found to be unifloral.

KEYWORDS: *Apis mellifera,* pollen loads, unifloral

INTRODUCTION

Honeybee *Apis mellifera* L. readily gather pollen from the flowers of many entomophilous species providing both nectar and pollen (Percival 1947; Rashad and Parkar, 1958; Vaissiere and Vinson, 1994). Nectar is a carbohydrate source while pollen supplies bees with protein, lipids, vitamins and minerals needed to rear larvae (Manning, 2001). Exogenous pollen may be introduced into a beehive in numerous ways: bees carry pollen to the hive in their pollen baskets (corbicula), pollen grains may fall from bees body parts into the nectar filled combs, airborne pollen may enter the hive via air currents, used wax combs are added to hives or imported pollen is fed to bees (Rouff and Bogdanov, 2004; Erdogon and Erdogon, 2014). Pollen grains in the honey not onlyreflect regional agriculture and forest vegetation but also the floral diversity and species of plants foraged by honeybees available in the vicinity of the apiary (Louveaux *et al*., 1978). Melissopalynology (study of pollens in relation to honeybees), therefore, is useful in determining and controlling the honeys geographical and botanical origin. This information has commercial value because honey of dominant floral type can bring higher price than honey of mixed or unknown floral sources as the unifloral honeys maintain always the same physico-chemical and organoleptic characteristics and are well appreciated for commerce (Barth, 2004). Though pollen analysis studies have been carried out from different parts of India (Bharghava *et al.,* 2009; Attri, 2010; Timande and Tembhare, 2010; Cherian *et al,* 2011; shubharani *et al*., 2012, Tiwari *et al*., 2012) but no such efforts has ever been made in Haryana. Hence the aim of the present work is to identify the pollen sources availed by *A. mellifera* during different season through melissoplaynological investigations of corbicular pollen and honey from Hisar, Haryana, India.

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MATERIAL AND METHODS

The materials required and methods followed in the present studies are described hereunder in detail. Ten samples of both pollen loads and honeys were collected from ten different hives of Research Apiary of Project Coordinating unit, All India Coordinated Research Project (AICRP) on Honey Bees and Pollinators, Haryana Agricultural University (HAU), Hisar (29.1605N 75.7204E) twice in a month from January, 2012 to December, 2012 except second fortnight of July and entire month of August due to sharp decline in its population upon foraging by bees in the garden nearby which was sprayed with insecticides. The honey bees reaching the hives after foraging were caught, the corbicular pollen from such bees were collected and observed for their floral identity. In some cases pollens were also collected from the hive for the same purpose. Honey bees were anesthetized with ethyl acetate. The pollen loads were then pushed off the hind legs into an individual specimen tubes.

Method given by Bilisik *et al*. (2008) was followed in which a piece of each pollen load was mixed with glycerine-jelly and stained using basic fuschin (Wodehouse, 1935). The honey samples for microscopic pollen analysis were prepared according to Salonen *et al*. (2009) by slight modified method recommended by International Commission for Bee Botany (Louveaux *et al*., 1978) in the laboratory as follows: ten grams of honey were dissolved in 20 ml of distilled water and centrifuged (10 min, 3500 rpm). The supernatant was disposed off and the sediment washed again with 20 ml of water. The supernatant was again removed after the second centrifugation (5 min, 3500 rpm) and the residue transferred using a Pasteur pipette onto a microscope slide, which was left to dry, covered by a piece of paper, until the next day. The sample area was subsequently covered with Kaiser's glycerol-gelatin and a coverslip, and again left to dry under paper for 24 hours.

The pollen grains were examined using ocular microscope assisted with computer and Videology USB Viewer Software Version 2.1.100 and compared with the reference pollen slides of the vegetation surrounding the hives.The reference pollen slides were prepared following the methodology of Schweitzer (2009). Minimum of 1000 pollen grains were counted per sample as recommended by Behm *et al*. (1996). From this data, the percentage of the each taxon of pollen grains was calculated and the average was worked out for each month. The unknown pollens were recorded as unidentified. Pollen types were classified into four types: predominant pollen (>45%), secondary pollen (16-45%), important minor pollen (3-15%) and minor (<3%) pollen. When one pollen type represented 45% of the total number of pollen grains, the sample was classified as unifloral honey (Louveaux *et al.,* 1978).

RESULTS AND DISCUSSION

The observed pollen types in the pollen loads are to be considered typical of the habitats and vegetation forms of the study area, allowing the identification of the floral origin of the pollen supply during the analysed period. The pollen types harvested by *A. mellifera* at Hisar included *Acacia katechu* (Mimosaceae), *Aegle marmelos* (Myrtaceae), *Azadirachta indica* (Meliaceae), *Brassica juncea* (Brassicaceae), *Callistemon lanceolatus* (Myrtaceae), *Cicer arietinum* (Papillionaceae), *Citrus sinensis* (Rutaceae), *Coriandrum sativum* (Apiaceae), Cucurbitaceae type (Cucurbitaceae), *Eucalyptus* sp. (Myrtaceae), *Gossypium hirsutum* (Malvaceae), *Helianthus annus* (Compositae), *Parthenium hysterophorus* (Asteraceae), *Peucedanum graveolens* (Apiaceae), *Phoenix dactylifera* (Palmae), *Pisum sativum* (Leguminosae), Poaceae type (Poaceae), *Pongamia glabra* (Leguminosae), *Psidium guajava* (Myrtaceae), *Raphanus sativus* (Brassicaeae), *Sesamum indicum* (Pedaliaceae), *Tagetes errecta* (Compositae), *Tamarindus indica* (Cesalpiniaceae), *Trianthema portulacastrum* (Aizoaceae), *Trifolium alexandrinum* (Papilionaceae), *Trigonella foenum-graecum*, *Ziziphus jujube* (Rhamnaceae) and unidentified. An analysis of pollen loads and honey samples collected from a single apiary revealed a total of 28 pollen types identified representing 25 genera and 19 families and a total of 26 pollen types representing 23 genera

and 18 families, respectively. Only one pollen type failed to be identified and two were identified to level of family. The pollen types varied both in time, frequency and species richness. The identified species belong to varying genera of native herbs, shrubs, grasses and trees.

The analysis of pollen loads of *A. mellifera* revealed mean per cent frequency of greater than 45 per cent in most of the loads with 100 per cent for *B. juncea* in January and 91.2 per cent for *Z. jujube* in July while, pollen loads of May, September and November were found to be multifloral with no predominant pollen types recorded. The maximum number of secondary pollen types (three) was recorded in pollen loads of September with maximum mean per cent frequency of 43.6 per cent for cucurbitaceae type followed by two pollen types in March with 25.3 per cent maximum mean frequency for *Eucalyptus* sp.. The pollen loads collected in the months of January and October recorded no important minor pollen types while the maximum number of important minor pollen types were recorded in November *viz.,P. sativum* (15.3%), cucurbitaceae type (7.7%), *B. juncea* (5.1%) and unidentified (11.9%) followed by May, *T. portulacastrum* (8.0%), *R. sativus* (6.9%) and *P. glabra* (3.0%) and *H. annus* (9.7%), *A. katechu* (9.5%) and *G. hirsutum* (8.9%) in June. The highest mean per cent frequency of minor pollen types was recorded at 2.4 per cent for *C. arietinum* in February followed by 2.1 per cent for poaceae in March. The pollen loads of January, July, September and November recorded no minor pollen types (Table 1).

The analysis of honey samples recorded mean per cent frequency of predominant pollen types at greater than 45 per cent in all samples except May, September and November which recorded no predominant pollen types (Table 2).The January, June and July samples recorded no secondary pollen types. The maximum number of secondary pollen type were recorded in March, *T. alexandrinum* (19.7%) and *Eucalyptus* sp. (19.9%), in May, *P. guajava* (34.5%) and cucurbitaceae type (38.2%) and in September cucurbitaceae type (44.3%) and poaceae type (24.6%). The each of April, July, September, October and December samples recorded two important minor pollen types with maximum mean per cent frequency of *P. dactylifera* (5.4%), *G. hirsutum* (7.8%), *S. indicum* (14.1%), unidentified (8.7%) and cucurbitaceae type (8.4%), respectively. The January, February and March recorded *Eucalyptus* sp. (9.8%), *C. sinensis* (8.1%) and *P. dactylifera* (7.4%), respectively. November month samples contained pollen grains of poaceae type (2.7%), unidentified (2.1%) and *P. hysterophorus* (1.4%). In the analysed honeys the most frequent pollen types (nine times) included cucurbitaceae type (January, March, May, June, July, September, October, November and December) and *Eucalyptus* sp. type (seven times) in January, February, March, April, May, November and December. The highest number of pollen types (nine) was recorded in May followed by eight each in April and November month samples while, the lowest number (three) was recorded in January (Table 3).Of the total honey samples analyzed, January, February, March, April, June, July, October and December month samples were found to be unifloral and the rest were multifloral. In the unifloral samples those with pollen type frequency greater than 45 per cent, the predominant pollen types were *B. juncea, C. sinensis, T. alexandrinum, P. guajava, Z. jujube, cucurbitaceae* type and *Eucalyptus* sp.

The pollen analysis of *A. mellifera* collected pollen loads and honeys from Hisar generated significant information pertaining to botanical origin of honeys, whether unifloral or multifloral and documentation of bee foraging plants, as well. The unifloral pollen from *B. juncea, C. sinensis, T. alexandrinum, P. guajava, Z. jujube,* cucurbitaceae and *Eucalyptus* sp. appear as the majority in the months from January and February, March, April, June, July, October and December, respectively representing the plants commonly found in the area. Some of the observed species and genera considered melittophilous had already been indicated as potential bee plants in Hisar region of Haryana (Sihag 1990a; Sihag 1990b; Mishra and Kaushik, 1992; Kaur and Sihag, 1994). The uniflorality in most of samples in the present investigations indicates selective behaviour and preferences of

Table 1. Mean per cent frequency of pollen types recorded in the pollen loads of *A. mellifera* at Hisar

Month	Pollen types			
	Predominant (>45%)	**Secondary (16-45%)**	**Important minor (3-16%)**	**Minor (<3%)**
January	*B. juncea* (100%)	-	-	
February	*B. juncea* (59.8%)	*T. foenum-graecum* (30.2%)	*C. sinensis* (6.6%)	*C. arietinum* (2.4%)
March	*C. sinensis* (51.2%)	*Eucalyptus* sp. (25.3%), *T. alexandrinum* (13.8%)	*P. dactylifera* (7.8%)	Poaceae (2.1%)
April	*T. alexandrinum* (64.0%)	*C. sinensis* (19.1%)	*A. indica* (9.2%), *C. sativum* (3.7%)	*P. glabra* (1.9%), *P. graveolens* (1.0%), *A. marmelos* (1.1%)
May	-	Cucurbitaceae (41.4%), *P. guajava* (38.5%)	*T. portulacastrum (8.0%), R. sativus* (6.9%) *P. glabra* (3.0%)	*C. lanceolatus* (2.0%)
June	*P. guajava* (70.0%)	-	*H. annus* (9.7%), *A. katechu* (9.5%), *G. hirsutum* (8.9%)	*T. indica* (1.9%)
July*	*Z. jujube* (91.2%)	-	*G. hirsutum* (8.8%)	-
August**	-	-	-	-
September	-	Cucurbitaceae (43.6%), Poaceae (25.4%), *S. indicum* (17.0%)	*T. errecta* (7.9%), *Unidentified (6.9%)*	-
October	Cucurbitaceae (55.6%)	Poaceae (24.4%), Unidentified (18.2%)	-	*S. indicum* (1.8%)
November	-	*Eucalyptus* sp. (39.0%), Poaceae (20.9%)	*P. sativum* (15.3%), Cucurbitaceae (7.7%), *B. juncea* (5.1%), Unidentified (1.9%)	-
December	*B. juncea* (32.9%)	Cucurbitaceae (7.5%), *P. hysterophorus* (3.8%)	*Eucalyptus* sp. (54.6%)	Unidentified (1.2%)

* Observations were not taken for second fortnight
** Observations were not taken for entire month

bees to a particular crop. This curious behaviour of bees is called floral fidelity. As a consequence of floral fidelity during certain period, almost all the pollens recorded in the present studies were unifloral, derived from a single species, corresponding to its flowering period. Also, floral fidelity could be related to the distance of the hives to floral sources, sometimes being more advantageous for bees to forage on single flowering species that occur in proximity rather than search for different flowers (Krebs and Davis, 1996). Similarly, the plant species which are recorded as predominant pollen types in the present studies were found to be in close proximity to the Research Apiary. The uniflorality and multiflorality have been reported from different parts of the country (Attri, 2010; Timande and Tembhare, 2010; Cherian *et al.,* 2011; Shubharani *et al*., 2012).

A colony of *A. mellifera* harvests many plant species, thus receiving good nutritional balance (Schmidt and Buchmann, 1993) that is reflected in the present studies were the plant species variability is greatest in the important minor pollen followed by the minor pollen group, secondary and predominant pollen groups. This seems to confirm

Table 2. Mean per cent frequency of pollen types from the analysis of honey samplescollected from hives at Hisar

Month	Pollen types			
	Predominant (>45%)	**Secondary (16-45%)**	**Important minor (3-16%)**	**Minor (<3%)**
January	*B. juncea* (88.3%)	-	*Eucalyptus* sp. (9.8%)	Cucurbitaceae (1.9%)
February	*B. juncea* (67.5%)	*T. foenum-graecum* (20.4%)	*C. sinensis* (8.1%)	*Eucalyptus* sp. (2.1%), *C. arietinum* (1.9%)
March	*C. sinensis* (48.3%)	*T. alexandrinum* (19.7%), *Eucalyptus* sp. (19.9%)	*P. dactylifera* (7.4%)	Cucurbitaceae (2.7%), Poaceae (2.0%)
April	*T. alexandrinum* (59.1%)	*C. sinensis* (23.9%)	*P. dactylifera* (5.4%), *Eucalyptus* sp. (3.1%)	*P. glabra* (2.6%), *C. sativum* (2.5%), *A. marmelos* (2.0%), *P. graveolens* (1.4%)
May	-	*P. guajava* (34.5%), Cucurbitaceae (38.2%)	*T. portulacastrum* (7.5%), *R. sativus* (6.3%), *C. sinensis* (6.0%)	*C. lanceolatus* (2.6%), *P. glabra* (2.4%), *Eucalyptus* sp. (1.3%), *P. dactylifera* (1.2%)
June	*P. guajava* (55.3%)	-	Cucurbitaceae (14.2%), *H. annus* (11.5%), *G. hirsutum* (6.3%), *C. sinensis* (6.0%), *A. katechu* (5.5%)	*T. indica* (1.2%)
July*	*Z. jujube* (79.1%)	-	*G. hirsutum* (7.8%), *P. guajava* (7.4%)	Culurbitaceae (2.9%), *H. annus* (2.8%)
August**	-	-	-	-
September	-	Cucurbitaceae (44.3%), Poaceae (24.6%)	*S. indicum* (14.1%), *Z. jujebe* (12.1%)	*P. guajava* (2.6%), *T. errecta* (2.3%),
October	Cucurbitaceae (54.3%)	Poaceae (27.7%)	Unidentified (8.7%), *S. indicum* (5.6%)	*Z. jujube* (2.3%), *P. guajava* (1.4%)
November	-	*Eucalyptus* sp. (39.4%)	Cucurbitaceae (23.2%), Poaceae (13.6%), *P. guajava* (12.9%), *B. juncea* (4.7%)	Poaceae (2.7%), Unidentified (2.1%), *P. hysterophorus* (1.4%)
December	*Eucalyptus* sp. (55.2%)	*B. juncea* (31.6%)	Cucurbitaceae (8.4%), *P. hysterophorus* (3.5%)	Unidentified (1.3%)

* Observations were not taken for second fortnight
** Observations were not taken for entire month

the view that variability is always small among pollen species in the dominant groups, while greater among minor pollen, important minor pollen and secondary pollen groups (Boff *et al.*, 2011; Sabo *et al*., 2011). This is expected when bees get access to flowers of different bee forage plants in the same period. The pollen types recorded in the present studies have been reported by many authors from different locations, Attri, 2010 (*Albizzia* spp., *Citrus* sp., Cucurbitaceous pollen*, D. sissoo, P. sativum, R. sativus, S. indicum, T. alexandrinum, T. foenum-graecum, Z. mays* etc.), Cherian *et al.,* 2011 (*A.*

Table 3.Types of honey and number of pollen types from analysis of hone samples collected from hives at Hisar

Month	Types of honey	Unifloral pollen type	Number of pollen types
January	Unifloral	*B. juncea*	**3**
February	Unifloral	*B. juncea*	**5**
March	Unifloral	*C. sinensis*	**6**
April	Unifloral	*T. alexandrinum*	**8**
May	Multifloral	———	**9**
June	Unifloral	*P. guajava*	**7**
July*	Unifloral	*Z. jujube*	**5**
August**	———	———	———
September	Multifloral	———	**6**
October	Unifloral	Cucurbitaceae	**6**
November	Multifloral	———	**8**
December	Unifloral	*Eucalyptus* sp.	**5**

* Observations were not taken for second fortnight
** Observations were not taken for entire month

indica, A. lebbeck, B. campestris and *P. guajava* as predominant pollens), Shubharani *et al*., 2012 (*Eucalyptus* sp., *H. annus, Mimosa* sp*., Z. mays* etc.) and Tiwari *et al*., 2012 (*C. sativum, Citrus* sp., Poaceous pollen etc.*).*

The microscopic analysis revealed that the genera represented in both pollen loads as well as in the honey were almost same. However, the higher frequency percentage is recorded in pollen loads than in honey samples. This might be due to part of the pollen used as food material for growth of brood and hence less pollen was taken into the super chamber. Though both, pollen loads and honey samples recorded same pollen types, but the timing of occurrence of these pollen types varied as some of the pollen types like *C. sinensis* (May and June) and *P. guajava* (September, October and November) were encountered in honeys during months, not coinciding with their flowering period. This might be due to sticking of these pollens inside the hives.Some resources utilized by honey bees were not observed in the cultivated field, such as *A. indica, Eucalyptus* sp., *P. dactylifera* and *T. indica*. However, they have been observed nearby on roads, bunds and in patches indicating that bees gathered resources from non-cultivated trees. However, the economically important plants constitute major part of the flora of this area. Thus, there is potential to produce considerable quantity of honey from these resources.

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Ecological studies on red ant *Oecophylla smaragdina* (Fab.)

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ABSTRACT: Seasonal variation in population, activity, interaction with other species of ants and effect of food provision with regard to red ant *Oecophylla smaragdina* was studied. The population and activity was maximum during summer months. Ant activity was positively correlated with ambient temperature. Red and the black ants *Tetraponera nigra*, *Paratrechina longicornis* were found to coexist whereas yellow crazy ant *Anoplolepis gracilipes* dominated and killed red ant members. Provisioning food such as chicken shank was found to increase the number of colonies rapidly.

KEY WORDS: *Oecophylla smaragdina,* abundance, inter specific interaction, food

INTRODUCTION

Ants are one of the most abundant and omnipresent arthropod groups on earth and are dominant in tropics and subtropics as scavengers and predators on many arthropods. Two humid-tropic species, *Oecophylla smaragdina* (Fab.) (Hymenoptera: Formicidae) in Asia and Australia and *O. longinoda* (Latreille) in Africa, exhibit similar biological traits. They are active throughout the year and their distribution and abundance depends on evergreen trees and shrubs. The genus *Oecophylla*, which is considered as a 'living pesticide' is one of the most impressive members of forest landscapes because of their dominance in local habitats, large body size, aggressiveness in addition to the peculiar nesting behaviour (Holldobler and Wilson, 1990). Offenberg (2015) reported that recent works on *Oecophylla* spp. showcase ants as highly efficient pest controllers and they can reduce pest numbers and their damage and increase yields in multiple crops. A number of ecologists, studying biological pest management in the tropics have suggested that the predatory power of *Oecophylla* is most outstanding among ants in their localities (Way and Khoo, 1992; Peng *et al*.,1999; Mele and Cuc, 2000). The efficiency of *Oecophylla* is comparable to chemical pesticides or higher, while at lower costs and they provide a rare example of documented efficient conservation biological control (Offenberg, 2015).

Peng *et al.* (2009) reported that the density of ants needed for effective protection was considered difficult to achieve under field conditions. So in order to augment red ants, its cultivation have to be undertaken. Here comes the importance in generating information on the effects of temperature, humidity, food provision, interactions with other ant species etc. on the ant activity and population build up which is undertaken in this study.

MATERIAL AND METHODS

Seasonal variation in population

The variations in the population of *O. smaragdina* in different seasons were studied by counting the

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live nests present on ten host plants throughout the year from March 2014 to March 2015 at 15 days intervals. The host plants included three mango trees and seven cinnamon trees present in the block No. 14 of college orchard of College of Agriculture, Padannakkad.

Measurement of ant activity

Ant activity was measured on two mango trees and three cinnamon trees, where the number of nests are almost the same. To measure the ant activity, the number of ants crossing 15 cm distance at the chest height of the host plant in 120 seconds time period was counted. Ant activity was measured during rainy, winter and summer months for a period of 30 days in each season. The measurement was done daily at 7 am, 11 am, 3 pm and 6 pm.

Interaction with other species of ants

Interaction between *O. smaragdina* and other ant species was studied by observing colonization by red ants on plants dominated by other ant species. *O. smaragdina* nests were placed on plants dominated by other ants within a height of 1 metre from the soil surface and the interaction between ants were observed. Red ant nests were collected from different trees like sapota, nut meg etc. Small branches on which the nests were built were cut carefully and collected directly in to plastic covers and tied properly. These nests were taken to the host trees and carefully tied on the host plant branches. The experiment was done on 10 selected cashew trees and 6 cowpea trellises. The study was conducted in cashew trees which were dominated by the two black ant species namely *Tetraponera nigra* Jerdon and *Paratrechina longicornis* (Latreille) and in cowpea trellises which were dominated by *Anoplolepis gracilipes.* The behaviour (aggressive / submissive) of the red ants towards other ants and colony establishment by red ants on the host plants were noted by taking observations for two months.

Effect of food provision

The study on the effect of food provision on the population *O. smaragdina* was done in 6 selected cashew trees. The experiment was conducted in November - December months. The number of live nests constructed on 3 trees which were provided with artificial food such as fish offal or chicken shank (lower part of leg without meat and with spur, claw and skin) was counted and compared with that of 3 trees which were not provided with food over a period of two months. Two pieces of chicken shank was provided on the trees at a height of 1 metre where more tender leaves are present.

RESULTS

In the study on seasonal variation in *O. smaragdina* population, it was observed that there is a general tendency of increase in the number of nests during summer months and decrease during monsoon period as shown in the figure 1. In the months of June - July when the heavy rain started, the number of nests of red ant started decreasing. At the beginning the average numbers of live nests were 9.3 per host plant which increased to 9.65 in April which then decreased to 6.7 in May 2014. Thereafter, a decreasing tendency was observed till September 2014. Then onwards increasing trend was seen till January 2015 followed by a decreasing trend.

Ant activity was measured during rainy, winter and summer months for a period of 30 days in each season daily at 7 am, 11 am, 3 pm and 6 pm and the observations show that the higher temperature in summer directly influenced the ant activity and a positive correlation was found between the ant activity and temperature. During the whole summer period, the average temperature was 31.56 and the ant activity was 58.56 where a weak positive correlation coefficient of 0.193 was seen. In rainy season, the temperature was less and so the ant activity also was less. It was observed that during raining, red ant prefer to stay inside the nest. The ant activity was reduced with the reduction in temperature which indicates a positive correlation. During rainy season the average temperature was only 2^0C less than that of summer, but the ant activity was only 28.79. This severe reduction

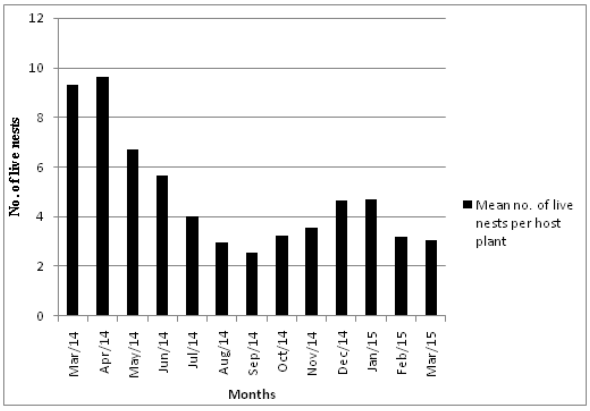

Fig. 1 Mean number of live nests constructed on host plants in every month from March 2014 to March 2015

during rainy season is due to the rains. It was observed that the average ant activity during the winter season was 12.79 with a temperature average of 28.16^{0}C. It can be concluded that in all the three seasons the relation between ant activity and temperature was positively correlated. The graphical representation of the data is shown in figure 2.

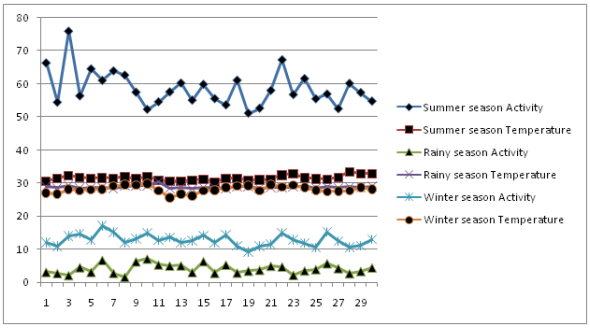

Fig. 2 Mean ant activity and temperature during the period of 30 days observed in three seasons

The observations on the ant activity and relative humidity for 30 days in each season show that the RH was higher in rainy season and a negative correlation was found between the ant activity and RH. During the whole summer period, the average RH was 69.29 % and the ant activity was 58.56 where negative correlation coefficient of -0.246 was observed. In rainy season, the RH was high and the ant activity was less. Here ant activity was reduced with the increase in RH which indicates a negative correlation. It was observed that the average ant activity during the winter season was 12.79 with RH average of 70.95. Here a positive correlation was obtained and the relation between ant activity and RH was negatively correlated in the other two seasons. The graphical representation of the data is shown in figure 3.

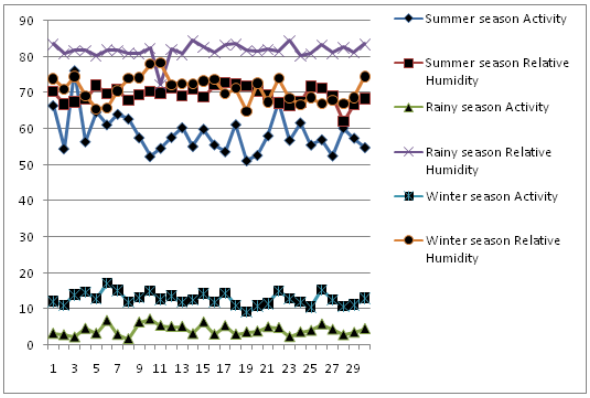

Fig. 3 Mean ant activity and relative humidity during the period of 30 days in three seasons

Mean ant activity and temperature at 7 am, 11 am, 3 pm and 6 pm in all the seasons are presented in Table 1. The ant activity was found less during morning hours when the temperature was less. Comparatively high activity was found in all other times. The average ant activity at 7 am was 12.84 where as it was 33.65 at 11 am, 32.06 at 3 pm and 30.70 at 6 pm, irrespective of the seasons.

Interaction between *O. smaragdina* and *Tetraponera nigra* and *Paratrechina longicornis* was studied by observing the number of nests built by red ant on 10 cashew trees dominated by the other two ant species for a period of one month and the data is presented in figure 4. The data showed that out of 10, on 5 trees red ants could not be established. But on 4 trees they could built one new nest each and on one tree 2 new nests were built. On first, third and sixth tree, there was no increase in nest construction during the period. But on fifth plant, the number of nests increased to 2, then to 3 and again to 2 during the period. The same trend was seen on ninth tree also. There was no direct fight

Fig. 4 Mean number of nests constructed by red ant on the trees dominated by black ants

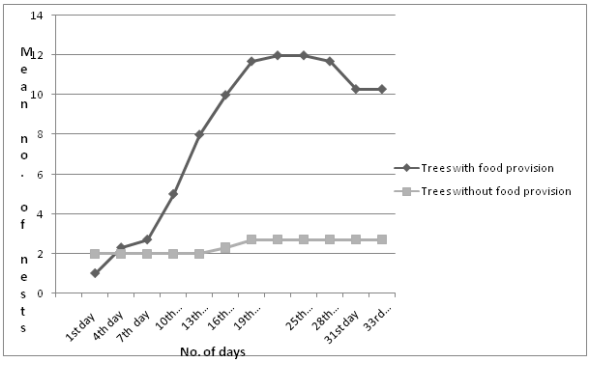

Fig. 5 Number of nests constructed by red ants on the trees provided with and without food

was noticed between black ants and red ant up on encounter. The interaction between them was found as submissive and they coexist.

Interaction between red ant and yellow crazy ant, *Anoplolepis gracilipes* was studied by observing the number of nests build by red ants on six cowpea trellises dominated by the yellow crazy ant. Here, the interaction between yellow crazy ants and red ant was found as aggressive and yellow crazy ant was dominant over red ant. When a red ant colony was introduced on a cowpea trellis colonized by yellow crazy ant, fierce fighting between the individuals of the two species was observed. Severe mortality was inflicted on the side of red ants when compared to yellow crazy ants. No red ant nest could be established on trellises harboured by yellow crazy ant and repeated introduction yielded the same result. Within 3 to 4 hours all the individuals of intruder were completely decimated.

The data on food provision done in six selected cashew trees are shown in figure 5. On an average, the number of nests on the cashew trees provisioned with food increased 10 times where as it was only 1.35 times when food was not provided over a period of 33 days which is significant.

DISCUSSION

In the study of seasonal variation in population, the recolonisation of red ant after the rainy season was less. It was because, when the red ant population was diminished on many host plants during the fag end of the rainy season, *Anoplolepis* got established and dominated. Heavy mulching at the base of the coconut trees provided during winter months provided a very good environment for *Anoplolepis* to harbour and multiply leading to the dominance of *Anoplolepis* in that area. *Anoplolepis* make their nests in soil and debris. In addition to this, weeding and subsequent tilling activity in the orchard led to clearing of ground vegetation of the area. This human intervention also made the recolonization of red ant difficult. In such areas, co existence of *Anoplolepis* and *Oecophylla* did not occur and *Anoplolepis* dominated. Mele and Cuc (2007) reported that if red ant's environment is disturbed by weeding, spraying, pruning etc, they will move to a quieter environment. This is in line with the results by Seguni *et al.,* (2011), who reported that, the effect of ground vegetation management on *Oecophylla longinoda* and its competitor, the ground-nesting ant, *Pheidole megacephala*, in a citrus orchard in Tanzania. When ground vegetation was present, *P. megacephala* tolerated *O. longinoda* and to some extent cohabited with this ant on citrus trees. After clean cultivation, *P. megacephala* displaced *O. longinoda* from tree crowns and became the sole occupant of the majority of trees.

Ant activity is severely reduced by rains. During rains they stay inside their nests. A simulation of rain like a spray of water also makes them less active and forces them to stay inside the nest, which is helpful in collecting the nests for spread to crops for pest management purpose. Peng and Christian (2005) reported that ant aggressiveness is greatly

Table 1. Mean ant activity and temperature at 7 am, 11 am, 3 pm and 6 pm during 30 days period

Sl.no	7 am		11 am		3 pm		6 pm	
	Activity	Temperature	Activity	Temperature	Activity	Temperature	Activity	Temperature
1	12.10	25.10	40.20	31.10	27.50	30.20	37.40	29.20
2	11.40	25.70	25.00	31.00	25.70	30.50	37.50	28.80
3	12.90	25.50	46.70	31.60	34.30	33.00	36.70	29.80
4	11.70	24.70	26.80	30.60	32.10	31.90	37.90	30.00
5	11.50	24.90	40.30	31.50	33.70	31.60	29.50	29.50
6	12.90	25.50	41.50	29.80	36.70	32.10	29.90	30.60
7	12.60	25.90	37.10	31.00	33.40	31.00	34.40	30.50
8	12.40	26.80	33.30	31.70	36.70	31.80	29.10	30.40
9	12.50	25.90	39.30	30.80	32.80	32.30	28.10	30.90
10	14.10	27.10	29.50	31.10	33.50	32.50	32.30	30.60
11	12.80	26.50	33.60	30.90	29.70	31.70	30.60	29.70
12	14.00	26.10	29.70	29.60	34.00	29.90	33.00	27.20
13	12.50	26.60	32.90	29.90	36.10	29.30	30.60	29.20
14	13.40	25.50	28.10	31.10	30.10	29.80	30.80	27.50
15	12.00	25.50	40.10	31.50	33.80	30.80	30.50	28.90
16	13.80	26.40	26.40	31.40	34.90	30.50	27.90	27.50
17	14.20	25.90	31.50	31.70	30.30	31.40	30.20	29.00
18	12.80	26.30	31.10	31.10	33.80	32.20	31.20	29.48
19	12.90	25.60	26.00	31.50	26.20	32.20	29.80	29.50
20	12.00	25.00	29.30	31.30	31.20	29.50	25.30	30.30
21	14.80	27.00	31.40	31.40	35.80	31.30	26.90	29.80
22	12.90	25.80	39.90	31.20	41.50	32.20	31.00	30.90
23	13.40	27.50	33.10	31.10	30.20	31.40	28.70	31.20
24	12.60	26.70	31.90	31.30	34.40	30.80	32.30	30.80
25	13.30	25.70	33.90	31.20	27.00	30.50	27.00	29.50
26	12.90	25.40	37.10	30.40	32.90	30.90	28.60	30.00
27	11.80	25.30	31.90	30.80	26.90	31.10	27.90	30.00
28	11.30	26.50	34.90	31.30	30.70	31.60	29.70	30.50
29	13.70	26.70	34.40	31.20	26.50	31.70	29.10	30.50
30	14.20	26.90	32.90	31.70	29.90	31.00	27.10	30.40
Mean	12.84	26.00	33.65	31.06	32.06	31.22	30.70	29.73

reduced by spraying water on trees prior to harvest. Their observations suggest that green ants either go back to their nests or stay on the underside of twigs and leaves when it is raining.

Food provision greatly increases the multiplication potential of the red ant evidenced by the increase in the number of nests within a short time. Chicken shank which was usually discarded by chicken shops was used in the experiment. Meat, dead rats and fish offal are also effective as a protenaceous food source as reported by Mele and Cuc (2007). This is in line with the results by Sreekumar *et al.,* (2010) who reported that the provision of food in the initial

days helps in the early establishment of the new colony and connecting the plants harboured by red ants using nylon ropes is found to be easy, if the colonies were found to be nearby. It was observed that, once provided these materials act as a source of food for about a month. The food material is not decayed because of the antibacterial activity of the ant secretions. Das *et al*., (2013) reported that the gastric secretions of *Oecophylla* have strong antibacterial activity against a range of gram negative and gram positive bacteria.

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First record of the longhorn beetle, *Rosalia lameerei* Brongniart (Cerambycidae: Cerambycinae: Compsocerini) from India, with additional descriptions of male

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ABSTRACT: Longhorn beetle, *Rosalia lameerei* Brongniart, 1891 is reported from India for the first time with re-description of morphological characters and first time descriptions of male genitalia.

KEYWORDS: Longhorn beetle, Compsocerini, *Rosalia lameerei,* male genitalia

INTRODUCTION

During the survey of cerambycid beetles in Northeast India, a colorful longhorn beetle identified as *Rosalia lameerei* Brongniart, 1891 was collected from Medziphema, Nagaland, its presence in Nagaland is the first record from India and an addition to the known list of species of Indian Cerambycidae. *Rosalia lameerei* was redescribed by Gahan (1906), but subsequently there are no detailed descriptions or illustrations of important characters. In this note, we present an additional description of *R. lameerei* along with the illustrations of the collected male. Also included are images of male genitalia for the first time.

MATERIAL EXAMINED

***Rosalia lameerei* Brongniart, 1891**

1 ♂ INDIA, Nagaland state, Dimapur district, Medziphema, 24.VII.2009, Dr. Pankaj Neog leg., Measurements (mm): body length 35; breadth at mid elytra 10; length and breadth of head 4 and 6; pronotal length 5 and breadth 7; elytral length 21; antennae 56.

RESULTS

General form and coloration

Body size moderately large. Entire body clothed with fine pubescence; head black, with narrow semicircle of bluish strip below eyes; pronotum bluish green, elytra greenish blue with four transverse black, velvety bands and spots (Fig. 1); body beneath blue (Fig. 2) with head, mesosternum and transverse bands on abdomen black (Fig. 3). Mandibles black, long and broad, with dorsal ridge and tooth (Fig. 4). Antennae longer than body by the last five joints, light blue in color, except for first two antennomeres and distal ends of each antennomere, which are black; apex of each antennomere with tuft of black hairs, these very prominent on antennomeres 3 to 6, rest of tufts are smaller (Figs. 1, 2). Pronotum with median

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prominent black patch on the anterior half, with two separate laterally placed black spots (Fig. 5); scutellum bluish green and heart shaped. Legs black, femora sub-fusiform with a narrow bluish band near apex; pro and mesotibiae slender, metatibiae swollen at apex and setose; meso and meta tarsi bluish dorsally and brownish ventrally.

Morphology

Head elongate, slightly sloping in front of eyes and narrowed at base; mandibles prominent, curved, sharply pointed, shining. Clypeus narrow, transverse; maxillary and labial palpi moderately long, black and covered with sparse pubescence; eyes large, finely facetted, emarginate. Antennae inserted at a distance in front of eyes, antennal tubercles moderately raised and area between them concave and coarsely punctate; short median longitudinal sulcus present between the antennal tubercles; antennae one and half times longer than body (in male), scape moderately long, slightly curved and gradually thickened from base towards apex, finely punctate (Fig. 5).

Prothorax broadest in middle and slightly narrower towards both ends, anterior margin slightly raised, unarmed at sides; prosternum slightly raised, bluish with sparse pubescence at sides, prosternal process narrow, slightly elevated (Fig. 7); mesosternum slightly depressed, mesosternal process bilobed reaching to half of meso-coxae; metasternum of moderate length. Metasternum broader than any other segment ventrally, rectangular. All legs moderately long, coxae prominent, femora sub-fusiform; mid and hind tibiae slightly dilated and more pubescent at distal end (Fig. 9); claws divergent.

Elytra almost parallel-sided, their apices moderately truncate. Of the four black bands and spots on elytra, the third one is represented by spots and other three by short bands except second, which is longer and broader.

Male genitalia

According to the terminology of Wallin *et al.* (2013), tegmen approximately 3.7 mm in length; lateral lobes straightly tapered from the middle to the narrowly rounded apices, with fine long setae (Figs. 13A-13C); median lobe plus median struts slightly curved (Figs. 10A-10C); longer than tegmen; dorsal plate bilobed and longer than ventral plate (Figs. 11A-11B); apex of the ventral plate straight; median foramen elongated; internal sac as long as median lobe (Figs. 11A-11B) with four semicircular basal pieces of armature, two arranged horizontally and two vertically. Tergite VIII broader than long (Figs. 12A-12B), apical margin bilobed, with short setae around sides.

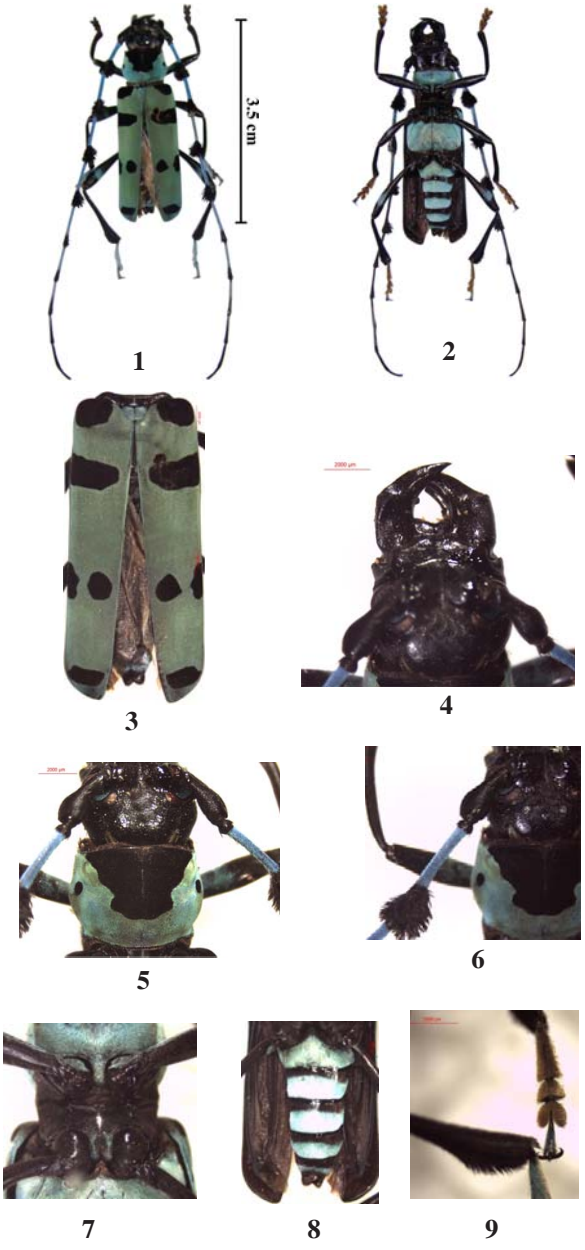
Distribution

China, Laos, Myanmar (Burma), Thailand, Taiwan?, Vietnam (Gahan 1906, Takakuwa 1994) and India, present report.

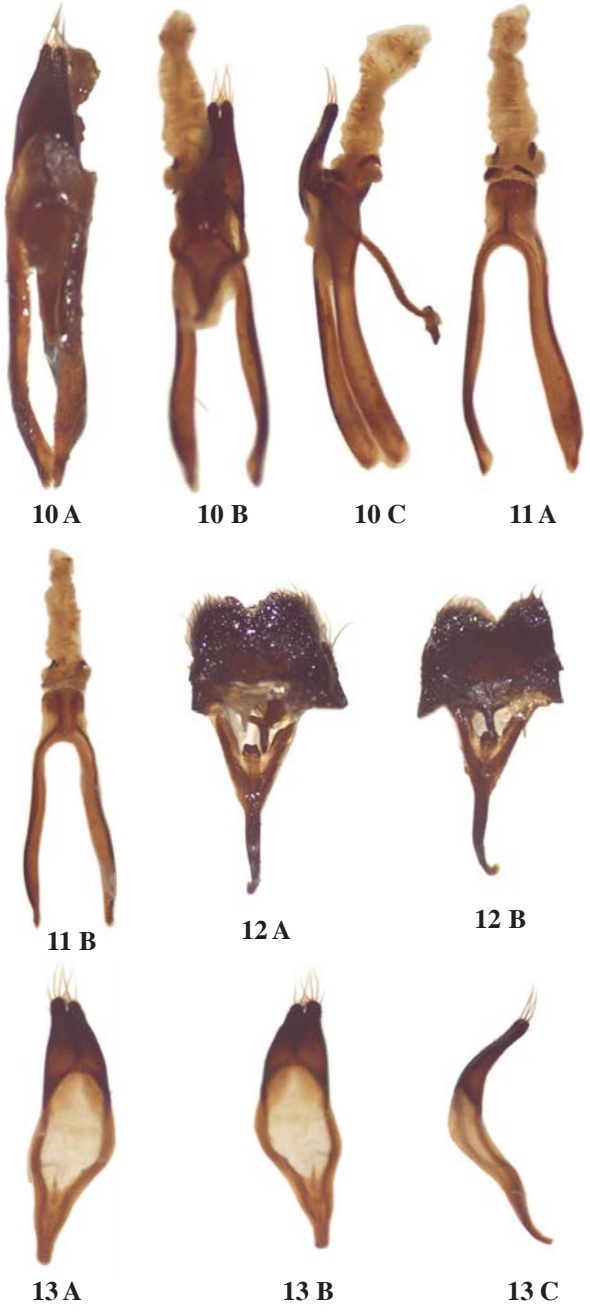
DISCUSSION

Rosalia lameerei is known to occur in Myanmar (Burma), Thailand, Laos, northern Vietnam, southwestern China and possibly, Taiwan so far (Gahan, 1906, Takakuwa, 1994). Previous papers dealing with Cerambycidae from Northeast India (Sengupta and Sengupta, 1981, Mukhopadhyay and Biswas, 2000, 2002, Mukhopadhyay and Halder, 2004, Agarwala and Bhattacharjee, 2012, Agarwala *et al.,* 2014, Mitra and Majumder, 2014 and Agarwala and Bhattacharjee, 2015) and the recent Nagaland survey by Mitra *et al.* (2016) do not list this species. Since Nagaland is located in the eastern most parts of India and Myanmar is adjacent country, occurrence of *R. lameerei* is not surprising. Lack of recent surveys in Northeast India does not allow full recognition of the biodiversity of these areas. The present observations on *R. lameerei* are in accordance with the descriptions given by Gahan (1906). Additional morphological characters and illustrations are furnished in this paper along with morphometry and details of male genitalia. Takakuwa (1994) studied genitalia of genus *Rosalia* but not *R. lameerei,* so these are first time descriptions of male genitalia.

Presently the genus *Rosalia* is placed in the tribe Compsocerini Thomson, 1864 of Cerambycinae.



Figs. 1-9. *Rosalia lameerei*. 1) dorsal habitus; 2) ventral habitus; 3) Elytra; 4) Mandibles; 5) Pronotum; 6) Antennomeres I-III; 7) Prosternal process; 8) Abdominal sternites; 9) mesotarsus and metatibial apex.



Figs. 10-13. *Rosalia lameerei*. 10) male genitalia. A) dorsal, B) ventral, C) lateral; 11) Median lobe and internal sac. A) dorsal, B) ventral, scale 200µm. 12) Tergite VIII and sternite VIII and XI. A) dorsal, B) ventral. 13) tegmen. A) dorsal, B) ventral, C) lateral, scale 100µm.

Five species of *Rosalia viz., R. (Eurybatus) decempunctata* (Westwood, 1848), *R. (Eurybatus) gravida* (Lameere, 1887), *R. (Eurybatus) lateritia* (Hope, 1831), *R. (Eurybatus) formosa* (Saunders, 1839) and *R. (Eurybatus) hariola* Thomson, 1860) are known to occur in Northeast India so far (Gahan, 1906); *Rosalia decempunctata* was reported from Tripura, Assam, Arunachal Pradesh and Sikkim (Mukhopadhyay and Halder, 2003); *R. gravida* from Himalayas; *R. lateritia* from Himalayas and Arunachal Pradesh; *R. hariola* from Sikkim (Mukhopadhyay and Halder, 2003) and *R. formosa*

from Assam, Meghalaya, Sikkim (Mukhopadhyay and Halder, 2003). Now *R. lameerei* becomes the sixth species of *Rosalia* found in India that can easily be distinguished by its characteristic greenish blue coloration of the body and four elytral black markings. All other species are reddish brown to rusty with variable elytral markings. This is the only Indian species that belongs to subgenus *Rosalia*, the other ones belong to the subgenus *Eurybatus* (Gahan, 1906).

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Insecticide resistance in field populations of tobacco caterpillar, *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae)

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ABSTRACT: Assessment of insecticide resistance in field populations of *Spodotera litura* collected from three districts of Kerala against certain commonly used insecticide molecules like chlorpyriphos, quinalphos, lambda cyhalothrin and cypermethrin showed that population collected from Aleppy was found to be susceptible for all the chemicals tested with resistance ratio -1, population collected from Thiruvananthapuram was found to be resistant with resistance ratios of 6.14, 2.46, 8.50 and 6.47 respectively followed by Pathanamthitta with resistance ratios of 2.62, 1.03, 2.29 and 1.34 for chlorpyriphos, quinalphos, lambda cyhalothrin and cypermethrin respectively.

KEY WORDS: *Spodoptera litura*, insecticide resistance, insecticides

INTRODUCTION

Tobacco caterpillar, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) is a polyphagous insect pest causing heavy damage to more than 115 species of plants and various agricultural crops (Atwal and Dhaliwal, 2009). It is also known as tobacco cutworm and is an native pest of several economically important crops grown all over the South Asian countries causing more than 26-100 % yield losses (Dhir *et al*., 1992). In order to alleviate the losses due to this pest, farmers often resorted to chemical interventions involving conventional organophosphates, carbamates, synthetic pyrethroids and some selected new chemistry molecules resulted in development of resistance and subsequent control failures (Kranthi *et al*., 2002; Abbas *et al.,* 2014; Saleem *et al.,* 2016).

In India, organophosphates and synthetic pyrethroids have been used as dominant insecticides in tobacco caterpillar management programs. In early 1980s, mid-1990s and early 2000s, its population in Andhra Pradesh and Tamil Nadu were highly resistant to synthetic pyrethroids, lindane, endosulfan, carbaryl and malathion (Kranthi *et al.,* 2002).

Resistance to insecticides is one of the major obstacles associated with the chemical control of insect pests. *S. litura* has been shown to be resistant to a wide range of insecticides, which has led to the unpredictable out breaks of the pest and subsequent crop failures (Ahmad *et al.,* 2007). *S. litura* from Indo-Pakistan subcontinent has been reported to evolve resistance to synthetic pyrethroids, organophosphates and carbamates (Saleem *et al.,* 2008). Resistance against old

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generation insecticides like quinalphos, monocrotophos, lindane and endosulfan was observed in the population of *S.litura* in Pakistan (Ahmad *et al.,* 2008).

Insecticide resistance is one of the most important phenomenon that threatens sustainable pest management programmes. Hence it is important to detect resistance at its budding level and monitor its increase and further spread so as to implement appropriate measures to restrain its increase. Hence the present study was undertaken to assess the resistance levels in field collected *S. litura* in South Kerala.

MATERIALS AND METHODS

The study pertaining to assessment of insecticide resistance in tobacco caterpillar, *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae) against the widely used chemicals like chlorpyriphos, quinalphos, lambda-cyhalothrin and cypermethrin was carried out in department of Agricultural Entomology, College of Agriculture, Vellayani during 2014-2015.

Field collection of larvae: The eggs and first instar larvae of *S.litura* collected from the infested vegetable fields grown in the three different districts of South Kerala *viz.* Aleppy (field with no previous history of pesticide application), Thiruvananthapuram and Pathanamthitta. The three populations were mass reared on artificial diet (Gupta *et al*., 2005) for continuous supply of second instar larvae for conducting bioassay.

Insecticides: The second instar larvae of *S.litura* were tested against different concentrations of commonly used insecticides belonging to different groups' *viz*. chlorpyriphos (classic 20 EC), quinalphos (ekalux 25 EC), cypermethrin (mehagit 10 EC) and lambda-cyhalothrin (karate 5 EC). Bioassay was carried out by using commercial grade formulations of insecticides.

Bioassay: Leaf dip bioassay as described by Hill and Foster (2000) was conducted to determine the response *S. litura* against the test insecticides. Fresh untreated castor leaves were collected from the field and dipped in accurate dilutions of test insecticides for 25-30 seconds with gentle agitation. The treated leaves were pat dried by using tissue papers to remove excess moisture and kept in polyvinyl containers (8cm × 11cm). Ten freshly moulted second instar larvae were released in to the plastic containers with treated leaves. The containers were covered with muslin cloth by using rubber bands to prevent the escape of the larvae. Each insecticide was treated at 7 different concentrations in three replications. Mortality was noted after 12, 24 and 48 hours of treatment. All the mortality data were corrected for the control treatment using Abbott's formula. The data was subjected to Probit analysis using SPSS software to calculate LC_{50} for each insecticide with 95 % corresponding fiducial limits. The population with least LC_{50} was considered as susceptible reference and degree of resistance attained by *S. litura* (Resistance ratio) was calculated by dividing the higher LC_{50} value of a population with a lower LC_{50} value of susceptible reference for each insecticide.

RESULTS AND DISCUSSION

Toxicity of chlorpyriphos to the population of *S. litura* collected from three locations is presented in Table 1. LC_{50} of chlorpyriphos observed in the population of *S. litura* collected from Aleppy was 0.64 ppm after 48 hours of treatment with fiducial limits (95 %) of 0.43-0.84 ppm. However, the LC_{50} of chlorpyriphos was 1.68 ppm after 48 hours of treatment in population of *S .litura* sampled from Pathanamthitta with fiducial limits of 1.10-3.73 ppm and higher LC_{50} of chlorpyriphos (3.93 ppm) were observed in population collected from Thiruvananthapuram with corresponding fiducial limits worked out to be 4.70 - 6.16 ppm respectively. The population of *S. litura* collected from Thiruvananthapuram and Pathanamthitta showed the resistance ratios of 6.14 and 2.62 respectively when compared to susceptible population collected from Aleppy.

Toxicity of quinalphos to the population of *S.litura* collected from three locations is presented in

Table 2. LC_{50} of quinalphos observed in the population of *S.litura* collected from Aleppy was 3.93 ppm after 48 hours of treatment with fiducial limits (95 %) of 3.31 – 4.41 ppm. However, the LC_{50} of quinalphos was 4.08 ppm after 48 hours of treatment in population of *S.litura* sampled from Pathanamthitta with fiducial limits of 3.54 – 4.53 ppm and it was 9.68 ppm in population collected from Thiruvananthapuram with corresponding fiducial limits worked out to be 4.16–5.28 ppm respectively. The population of *S. litura* collected from Thiruvananthapuram and Pathanamthitta showed the resistance ratios of 2.46 and 1.03 and respectively.

Toxicity of lambda-cyhalothrin to the population of *S. litura* collected from three locations is presented in Table 3. LC_{50} of lambda-cyhalothrin observed in the population of *S.litura* collected from Aleppy was 3.05 ppm after 48 hours of treatment with fiducial limits (95 %) of 2.72-3.36 ppm. However, the LC_{50} of lambda-cyhalothrin was 7.00 ppm after 48 hours of treatment in population of *S. litura* sampled from Pathanamthitta with fiducial limits of 6.31-7.66 ppm and it was 25.93 ppm in population collected from Thiruvananthapuram with corresponding fiducial limits worked out to be 22.31-29.61 ppm respectively. The population of *S. litura* collected from Pathanamthitta showed the resistance ratio of 2.29 and higher resistance ratio of 8.50 fold was noticed in population of *S. litura* collected from Thiruvananthapuram.

Toxicity of cypermethrin to the population of *S. litura* collected from three locations is presented in Table 4. LC_{50} of cypermethrin observed in the population of *S.litura* collected from Aleppy was 1.98 ppm after 48 hours of treatment with fiducial limits (95 %) of 3.27-4.30 ppm. However, the LC_{50} of cypermethrin was 2.67 ppm after 48 hours of treatment in population of *S.litura* sampled from Pathanamthitta with fiducial limits of 2.24-3.03 ppm and it was12.83 ppm in population collected from Thiruvananthapuram with corresponding fiducial limits worked out to be 10.49-14.77 ppm respectively. The population of *S. litura* collected from Pathanamthitta showed the resistance ratio of 1.34 and higher resistance ratio of 6.47 fold was

Table 1. LC_{50} values of chlorpyriphos tested with different selected populations of *S. litura*

Location	LC_{50} (ppm)	FL at 95% CL		χ^2	Slope(± SE)	df	Resistance ratio based on LC_{50}
		Lower	Upper				
Thiruvananthapuram	3.93	4.70	6.16	8.84	2.75 (± 0.317)	7	6.14
Pathanamthitta	1.68	1.10	3.73	7.54	1.81 (± 0.257)	6	2.62
Aleppy	0.64	0.43	0.84	5.07	1.62 (± 0.293)	6	1

LC_{50} – Lethal concentration

Table 2. LC_{50} values of quinalphos tested with different selected populations of *S. litura*

Location	LC_{50} (ppm)	FL at 95% CL		χ^2	Slope(± SE)	df	Resistance ratio based on LC_{50}
		Lower	Upper				
Thiruvananthapuram	9.68	4.16	5.28	11.87	3.15 (± 0.261)	14	2.46
Pathanamthitta	4.08	3.54	4.53	3.30	3.67 (± 0.438)	8	1.03
Aleppy	3.93	3.31	4.41	4.18	3.38 (± 0.427)	8	1

LC_{50} – Lethal concentration

Table 3. LC_{50} values of lambda-cyhalothrin tested with different selected populations of *S. litura*

Location	LC_{50} (ppm)	FL at 95% CL		χ^2	Slope(± SE)	df	Resistance ratio based on LC_{50}
		Lower	Upper				
Thiruvananthapuram	25.93	22.31	29.61	4.64	1.40(± 0.218)	14	8.50
Pathanamthitta	7.00	6.31	7.66	1.11	1.45 (± 0.183)	10	2.29
Aleppy	3.05	2.72	3.36	0.939	1.42 (± 0.178)	10	1

LC_{50} –Lethal concentration

Table 4. LC_{50} values of cypermethrin tested with different selected populations of *S. litura*

Location	LC_{50} (ppm)	FL at 95% CL		χ^2	Slope(± SE)	df	Resistance ratio based on LC_{50}
		Lower	Upper				
Thiruvananthapuram	12.83	10.49	14.77	12.07	1.13 (± 0.179)	14	6.47
Pathanamthitta	2.67	2.24	3.03	0.817	1.35 (± 0.301)	6	1.34
Aleppy	1.98	1.27	2.15	6.541	1.24 (± 0.219)	6	1

LC_{50} –Lethal concentration

noticed in population of *S. litura* collected from Thiruvananthapuram.

The *S. litura* population collected from Thiruvananthapuram and Aleppy had the maximum andminimum LC_{50} values. However, data showed that *S. litura* populations collected from aleppy and Pathanamthitta are on par against quinalphos with reference to the overlapped fiducial limits, while resistance levels of the three populations were significantly different with respect to other test chemicals chlorpyriphos, cypermethrin and lambda-cyhalohrin.

Genetic inheritance and indiscriminate application of insecticides are the two major factors responsible for resistance phenomenon in insects. Tobacco caterpillar has a short life cycle with very high fecundity as a result it is often exposed to multiple sprays of insecticides used for containing it which led to high selection pressure which finally resulted in resistance development. The results of the present study are in close conformity with the findings of Kranthi *et al.* (2001, 2002) who also reported the insecticide resistance in *S. litura* against the chlorpyriphos, quinalphos and cypermethrin in India. Though several research works have been conducted on insecticide resistance against tobacco caterpillar, studies in Kerala was scanty. Thus the present study was undertaken as a maiden attempt in assessing the extent of insecticide resistance of *S.litura* in Kerala. Further studies have to be taken up to delay the development of resistance through various management programmes.

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Review of the leafhopper tribe Adelungiini (Hemiptera: Cicadellidae: Megophthalminae) from the Indian subcontinent

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ABSTRACT: Two known species of Adelungiini from India (Rajasthan) and Pakistan are redescribed and illustrated. These include one new combination, *Assiuta omani* (Kameswara Rao & Ramakrishnan) **comb. nov**. and the other species being *Platyproctus maculatus* (Pruthi). The leg chaetotaxy and female genitalia of these two species are described and illustrated for the first time. In addition, male genitalia of the two other species of *Assiuta* Linnavuori namely, *A. camena* Linnavuori and *A. salina* Lindberg are illustrated. A revised key is given to distinguish the two tribes recognised from the region (Agalliini and Adelungiini). © 2017 Association for Advancement of Entomology

KEY WORDS: *Assiuta, Platyproctus, Symphypyga*, morphology

INTRODUCTION

Members of the tribe Adelungiini are highly specialised leafhoppers restricted to Old World deserts, breeding exclusively on xeric plants of the genera *Atraphaxis, Calligonum* (Polygonaceae)*, Eremosparton, Smirnovia* (Fabaceae)*, Halostachys, Haloxylon, Hammada, Iljinia, Kalidium, Salsola, Traganum* (Amaranthaceae) and *Zygophyllum* (Zygophyllaceae) (Emeljanov 1975). The tribe is small containing 12 genera and 62 species in the world today (Metcalf 1966, Linnavuori 1969, Emeljanov, 1975, Al-Neamy & Linnavuori, 1982), of which two are present in India (see key below). Pruthi (1930) described *Symphypyga maculatus*, the first species of Adelungiini from the subcontinent from Lyallpur, Pakistan and later, Kameswara Rao & Ramakrishnan (1983) described *Symphypyga omani* from Pilani, India. Emeljanov (1975) revised the tribe Adelungiini and transferred *S. maculatus* (Pruthi) to the genus *Platyproctus* Lindberg. In this paper, both the species are redescribed and illustrated with details of the female genitalia and leg chaetotaxy given for the fist time and in addition, *S. omani* is moved to the genus *Assiuta* Linnavuori **comb. nov.** Information on the host plants and biology of both the species of Adelungiini is not known. In view of the overlapping external morphological characters of the two recognised tribes from the region (Agalliini and Adelungiini), a revised key to distinguish these tribes based on male and female genitalia is also given (see Discussion).

The material studied in the present work came from the following depositories preceded by the abbreviations used in the text.

BMNH The Natural History Museum, London, United Kingdom

* Author for correspondence

IRSNB Institut Royal des Sciences Naturelles de Belgique, Brussels, Belgium

NPC National Pusa Collection, Indian Agricultural Research Institute, New Delhi, India

UASB Department of Entomology, University of Agricultural Sciences, Bengaluru, India

ZSI Zoological Survey of India, Kolkata, India

Taxonomy

Key to genera of Indian Adelungiini
(Based on Linnavuori, 1969)

1. Face with lora swollen, raised above surface of genae (Fig. 11,12)..... *Assiuta* Linnavuori

- Face with lora neither swollen nor raised above surface of genae (Fig. 9,10) .....*Platyproctus* Lindberg

Genus *Assiuta* Linnavuori

Assiuta Linnavuori 1969: 212-213. Type species: *Melicharella salina* Lindberg, by original designation.

Remarks: In addition to the Indian species of this genus described below three other species are known. Males of two species, *A. camena* Linnavuori (1 male, W. Assiut, Egypt, 1.iv.1932, Dr H. Priesner, determined by R. Linnavuori in NMWC, Figs 50-51) and *A. salina* Lindberg (1 male, Spain, Canary Islands, Fuerteventura, Corralejus, 27.iii.1953, Lindberg, determined by R. Linnavuori in NMWC Figs 52-56) were examined. The third species, *A. hieroglyphica* (Bergevin) found in Algeria and Tunisia was not examined.

However, in both *Assiuta omani* (Kameswara Rao and Ramakrishnan), **comb. nov**. and *A. camena* Linnavuori, the author noted that the aedeagus is not compressed, but cylindrical. The chaetotaxy of the forefemora: anteroventral row of setae (AV) prominent and stouter than other setae, intercalary setae (IC) 9-10 in number, slender and almost in a straight line; anterodorsal row (AD) with a row of 8 slender setae (Fig. 36). Metbasitarsus with one row of platellaelike setae, apical transverse row with two elongate setae intermediate between normal seta and platellae (Fig. 37). Davis (1975) and Al'Neamy & Linnavuori (1982) discussed the atypical scultpturing of the first pair of valvulae of the *A. hieroglyphica* (as *Platyproctus hieroglyphicus*) and *A. camena*, respectively. In Agalliini and Adelungiini, the first pair of valvulae have papillose or reticulate sculpturing, however, in the species of *Assiuta* examined, the sculpturing is strigate.

***Assiuta omani* (Kameswara Rao & Ramakrishnan) comb. nov.**
(Figs. 5-8, 11-12, 17-21, 36-49)

Symphypyga omani Kameswara Rao & Ramakrishnan 1983: 21-23, Figs. 1-9.

Colour: Grey with dark brown maculations on head, thorax and forewings as shown in figures 5 - 8. Transverse connected spots on vertex dorsad of ocelli and between eyes, and on anterior 3/4th of pronotum more prominent. Forewing venation prominent, dark brown.

Male genitalia: Male pygofer in lateral view longer than height, lobe produced posteriorly, with a dorsal submarginal pigmented thickening, dorsal margin almost straight, ventral margin strongly excavated about basal third, anterior margin with short dorsal apodeme. Subgenital plates fused basally, longer than wide, shorter than pygofer in length. Anal collar well sclerotized but not produced into a process. Style with outer fork shorter than inner fork, in dorsal view gradually narrowed to an acute point, in posterodorsal view strongly curved, with a tooth at midlength ventrally, and area proximad of it sculptured, distal half thin and long. Connective triangular with rather uneven lateral margins, anterior median process well developed. Aedeagus with well developed but short dorsal apodeme, shaft gradually curved anteriorly, ventral margin notched near base, and with series of lateral marginal short denticles arranged in one row, in posterodorsal view, apex with two prominent projections, gonopore apical.

Female genitalia: Ovipositor exceeding pygofer in ventral view. Seventh sternite in unprocessed abdomen, appears to have straight posterior margin with a median concave excavation and longer medially than preceding sternite. In processed abdomen, the seventh sternite medially broadly produced with lateral acute angles, medially with broad V-shaped excavation, surface covered with short setae. Eighth sternite also well developed, unpigmented and as broad as seventh but longer than seventh sternite, with a rectangular anterior projection extending into fifth visible abdominal segment. First and second pair of valvulae much broader compared to those of *P. maculatus* and straighter. First pair of valvulae with strigate sculpturing occupying distal 0.75 length but not attaining dorsal margin and the latter feebly serrate distally (Figs. 17-19). Second valvulae with toothed area crenulated, occupying distal 0.2 length (Figs. 20-21).

Measurements: Male 4.4 mm long, 1.65 mm wide across eyes and 1.4 mm wide across hind margins of pronotum. Female 4.7 mm long, 1.8 mm wide across eyes and 1.6 mm wide across hind margins of pronotum.

Type material examined. INDIA: Rajasthan: Holotype male, Pilani, Light, Oct.1965, Dr.Kundu (NPC). Paratype, 1 female, same data as holotype (NPC).

Other material examined: INDIA: 1 male, Rajasthan: Sri Kolayatji, 1.i.1975, S.L. Gupta (NPC).

Remarks: Kameswara Rao & Ramakrishnan (1983) described this species based on one male holotype and two male paratypes collected from Pilani, Rajasthan at light. The NPC collection has several specimens from Sri Kolayatji, Rajasthan, erroneously named as paratypes of this species as they have not been indicated in the original article. Among these only one male studied here belongs to this species whereas the others belong to *Platyproctus maculatus* (Pruthi). *A. omani* resembles *A. camena* Linnvuori closely, but can be differentiated from the latter by the less strongly curved aedeagal shaft, more numerous lateral denticles on the aedeagal shaft and the subgenital plates are more elongate compared to those in *A. camena*.

Genus *Platyproctus* Lindberg

Platyproctus Lindberg 1925: 112. Type species: *Platyproctus tessellatus* Lindberg by original designation.

Remarks: The fore femoral chaetotaxy is similar to that in *Assiuta*, but the intercalary row of setae are stouter. The first pair of valvulae have reticulate sculpturing compared to that in *Assiuta* where the sculpturing is strigate.

Platyproctus maculatus (Pruthi)

(Figs. 1 - 4, 9 - 10, 13 - 16, 23 - 35)

Symphypyga maculatus Pruthi 1930:15-17, Text figs. 18-20, Plate II, figs. 3, 3a.

Platyproctus maculatus (Pruthi): Emeljanov 1975: 108.

Colour: Paler specimen dirty white with brown markings as shown in Figs. 1 - 4 and 9 - 10, and darker specimens grey with dark brown markings. A stripe across eyes above ocelli on vertex, pink to reddish, more prominent in females than in males.

Male genitalia: Male pygofer longer than height, with shorter pygofer lobe compared to that in *Assiuta*; lobe with dorsal submarginal pigmented thickening continued along the posterior margin; anterior margin of pygofer with well developed dorsal apodeme. Subgenital plate distally blunt and dorsally curved. Anterior margin of tenth segment sclerotized and collar-like, but not produced into a process. Style with outer fork shorter than inner one, inner fork with a tooth on ventral margin at midlength, fork beyond tooth narrowed, apex hooked. Connective rather triangular, with lateral margins slightly sinuate, posterior angle rimmed,

anterior margin deeply emarginate. Aedeagus with short but well developed dorsal apodeme, shaft almost straight and with lateral flanges in basal half, curved anteriorly and tubular in distal half, gonopore subapical.

Female genitalia: Ovipositor slightly exceeding pygofer in ventral view. Seventh sternite in unprocessed abdomen, rather transparent, with straight posterior margin with a median slightly convex lobe and longer medially than the preceding sternite. In processed abdomen, seventh sternite narrowed posteriorly with lateral obtusely rounded angles, with short median lobe with median V-shaped excavation, surface covered with short setae. Eighth sternite well developed, pigmented, semi-circular and much shorter than seventh sternite.The first pair of valvulae thinner, strongly dorsally curved, with reticulate sculpturing occupying distal 0.33 length and attaining dorsal margin; strongly crenulated along dorsal apical region (Figs 13-14). The second pair of valvulae also strongly dorsally curved, thin with apex rather obliquely truncate and two types of toothed area, proximal area with much broader teeth with secondary dentition and the apical region with crenulate teeth without secondary dentition (Figs. 15 - 16).

Measurements: Male 4.4 - 4.7 mm long, 1.5 - 1.6 mm wide across eyes and 1.2-1.3 mm wide across hind margin of pronotum. Female 4.8 - 4.9 mm long, 1.6 mm wide across eyes and 1.4 mm wide across hind margins of pronotum.

Type material examined: PAKISTAN: Syntype male, Punjab: Lyallpur, September, 1921, H.S. Pruthi, syntype female same data but collected on October, 1929, at light. A.R. Rahaman (ZSI).

Other material examined. INDIA: Rajasthan: 1 male, Pilani, A.S. Sohi (UASB); 3 males, Sri Kolayatji, 1.i.1975, in light dome, S.L. Gupta (NPC); 13 males, 36 females, Vasmat, viii.1955, P.S. Nathan (IRSNB); 1 male, Bikaner, 295m, 6.viii.2015, at light, Yeshwanth, H.M. (UASB).

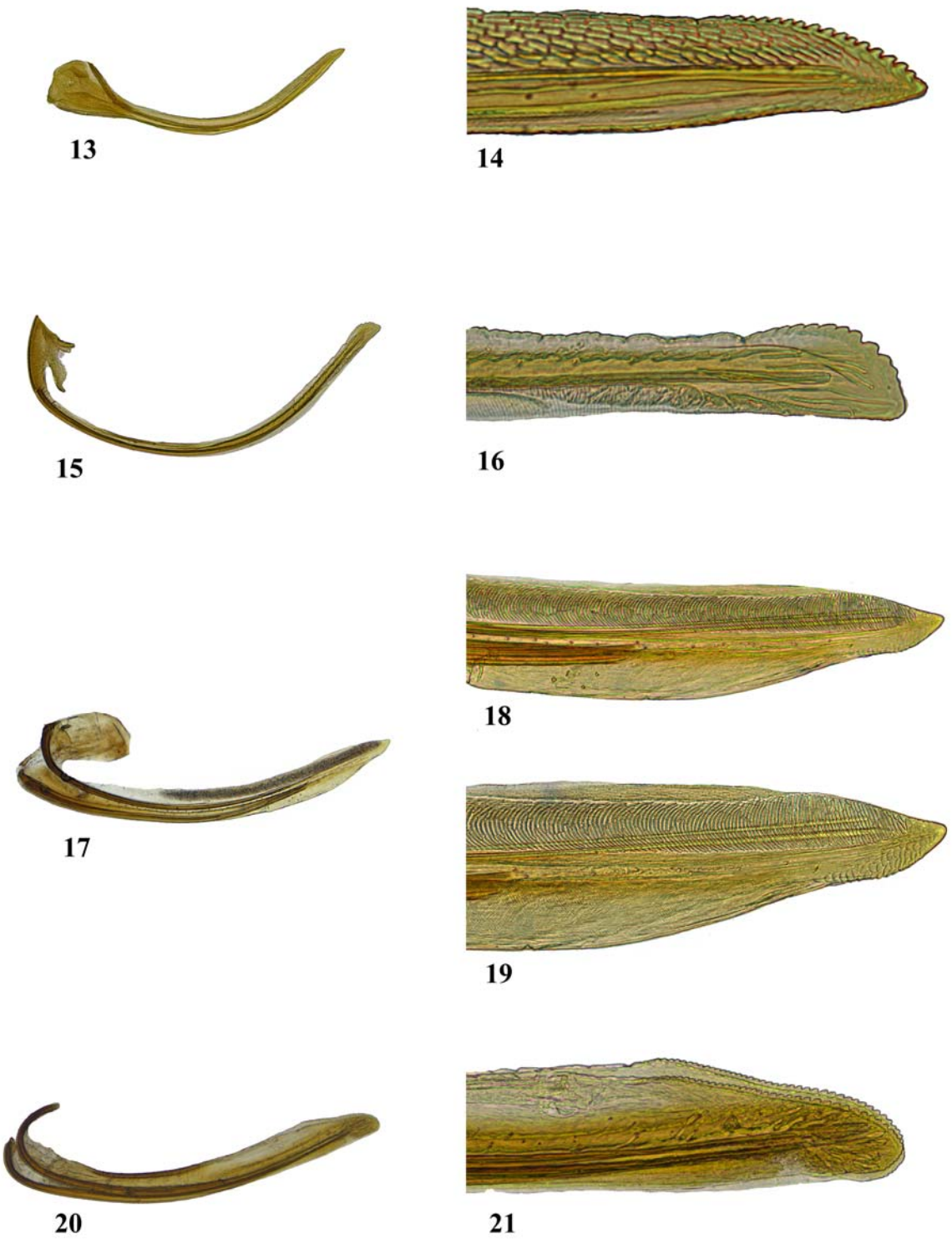
Remarks: Pruthi (1930) described this species based on two 'holotype No 528-529/H7'and unspecified number of other specimens from 'Lyallpur, Punjab; September, 1921 (H.S. Pruthi), at Light Trap; October, 1929 (A.R. Rahman), at Light Trap." These are considered here as syntypes (see Viraktamath 1981:7).

DISCUSSION

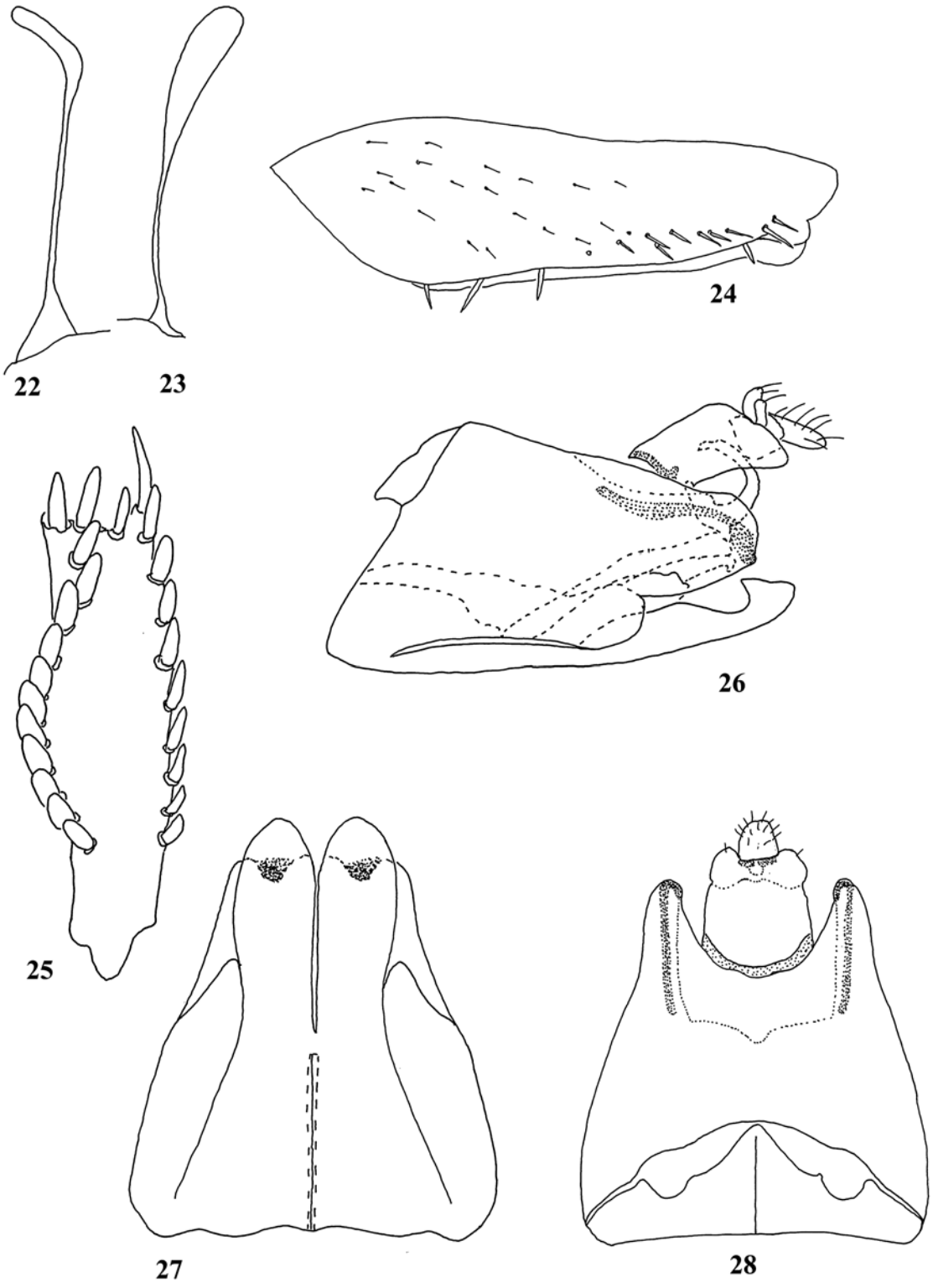
Oman *et al*. (1990) considered the group based on the genus *Adelungia* Melichar as a subfamily (Adelungiinae) with two tribes, Achrini and Peyerimhoffiolini. However, Dietrich (2005) treated this group as a tribe in the subfamily Megophthalminae, the other tribes included in the subfamily are Agalliini, Evansiolini and Megophthalmini. The tribes Adelungiini and Agalliini are very similar. They are usually separated by the presence or absence of reticulate venation of the forewings and complete or incomplete clypeal suture on the faces respectively (Dietrich, 2005). However, some agalliine genera namely, *Dryodurgades* Zachvatkin, *Durgula* Emeljanov and *Multinervis* Li and Li, have forewings with reticulate venation as in Adelungiini and *Agallia* Curtis, *Anaceratagallia* Zachvatkin, *Formallia* Viraktamath, *Hemagallia* Viraktamath and *Paulagallia* Viraktamath have complete clypeal suture that is either transverse or arcuate, as in Adelungiini. However, the two tribes differ in the shape of the connective in the male genitalia and sculpturing of the dorsoapical margin of the first pair of valvulae. Adelungiini have long, rather triangular connective in the male and the aedeagus is relatively small compared to the shorter, more or less broad connective and relatively large aedeagus in Agalliini. Only in the case of *Humpatagallia* Linnavuori and Viraktamath of the tribe Agalliini, is the connective long and the aedeagus relatively small but here the connective is rod shaped. The female first pair of valvulae in Adelungiini has the dorsoapical margin either serrate or crenulate whereas in Agalliini this margin is smooth (Al-Neamy and Linnavuori 1982). Thus these two tribes can be separated by the following key.

1. Female first pair of valvulae with dorsoapical margin serrate or crenulated (Figs. 14,18);

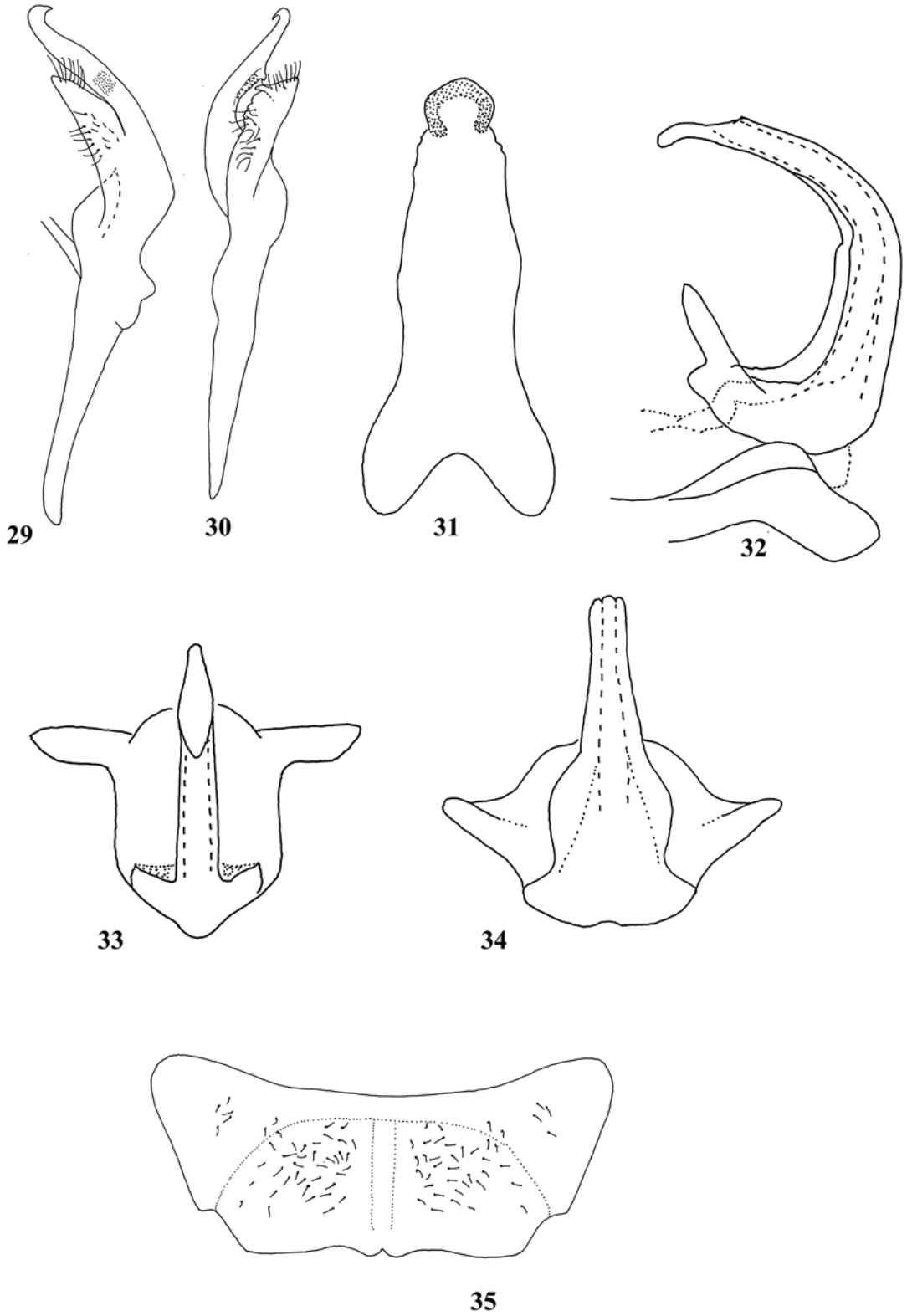
Figs. 1-12. Species of Adelungiini, 1-4. *Platyproctus maculatus* (Pruthi), male and female dorsal and lateral habitus, respectively; 5-8. *Assiuta omani* (Kameswara Rao & Ramakrishnan) comb. nov., male and female dorsal and lateral habitus, respectively. 9-10. *P. maculatus* (Pruthi), male and female face, respectively;



Figs. 13-21. Female valvulae of Adelungiini. 13-16. *Platyproctus maculatus* (Pruthi): 13 - First pair of valvula, lateral view; 14 - Apex of first pair of valvulae, magnified; 15 - Second pair of valvulae, lateral view; 16 - Apex of second pair of valvula magnified. 17-21. *Assiuta omani* (Kameswara Rao & Ramakrishnan) 17 - First pair of valvula, lateral view; 18-19. Apices of first pair of valvulae, magnified; 20 - Second pair of valvulae, lateral view; 21 - Apex of second pair of valvulae magnified.



Figs. 22-28. Species of Adelungiini. 22-23. Anteriortentorial arms of *Platyproctus maculatus* and *Assiuta omani*, respectively. 24-28. *P. maculatus*: 24 - Chaetotaxy of fore femur, mesal view; 25 - Chaetotaxy of metabasitarsus, ventral view; 26 - Male genital capsule, lateral view; 27 - Male genital capsule, ventral view; 28 - Male genital capsule, dorsal view.



Figs. 29-35. ***Platyproctus maculatus*****: 29, 30. Male style, dorsal and lateral view, respectively; 31 - Connective, dorsal view; 32 - Aedeagus and part of connective, lateral view; 33 - Aedeagus, dorsal view; 33 - Aedeagus, posterodorsal view; 35 - Female seventh sternite, ventral view.**

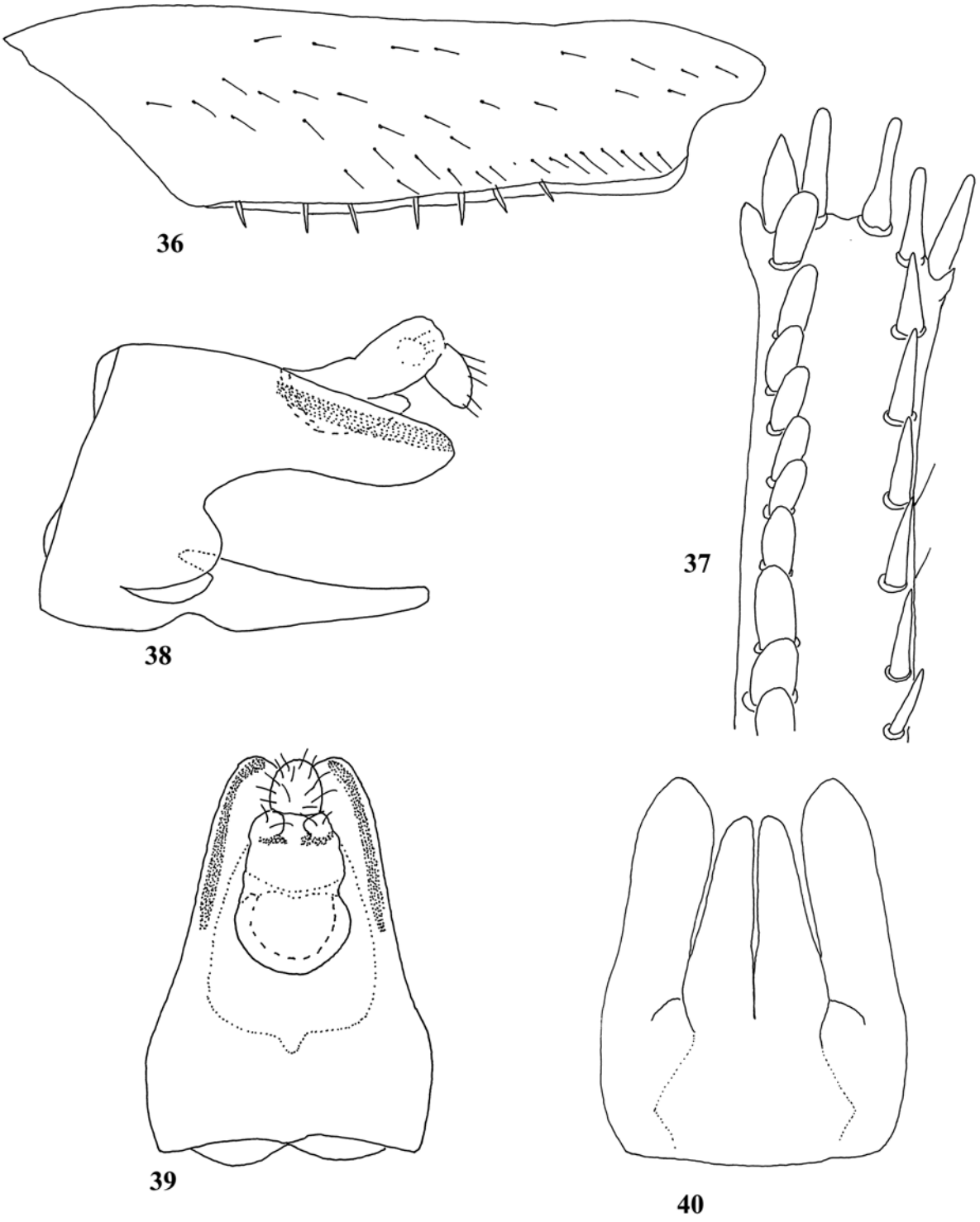
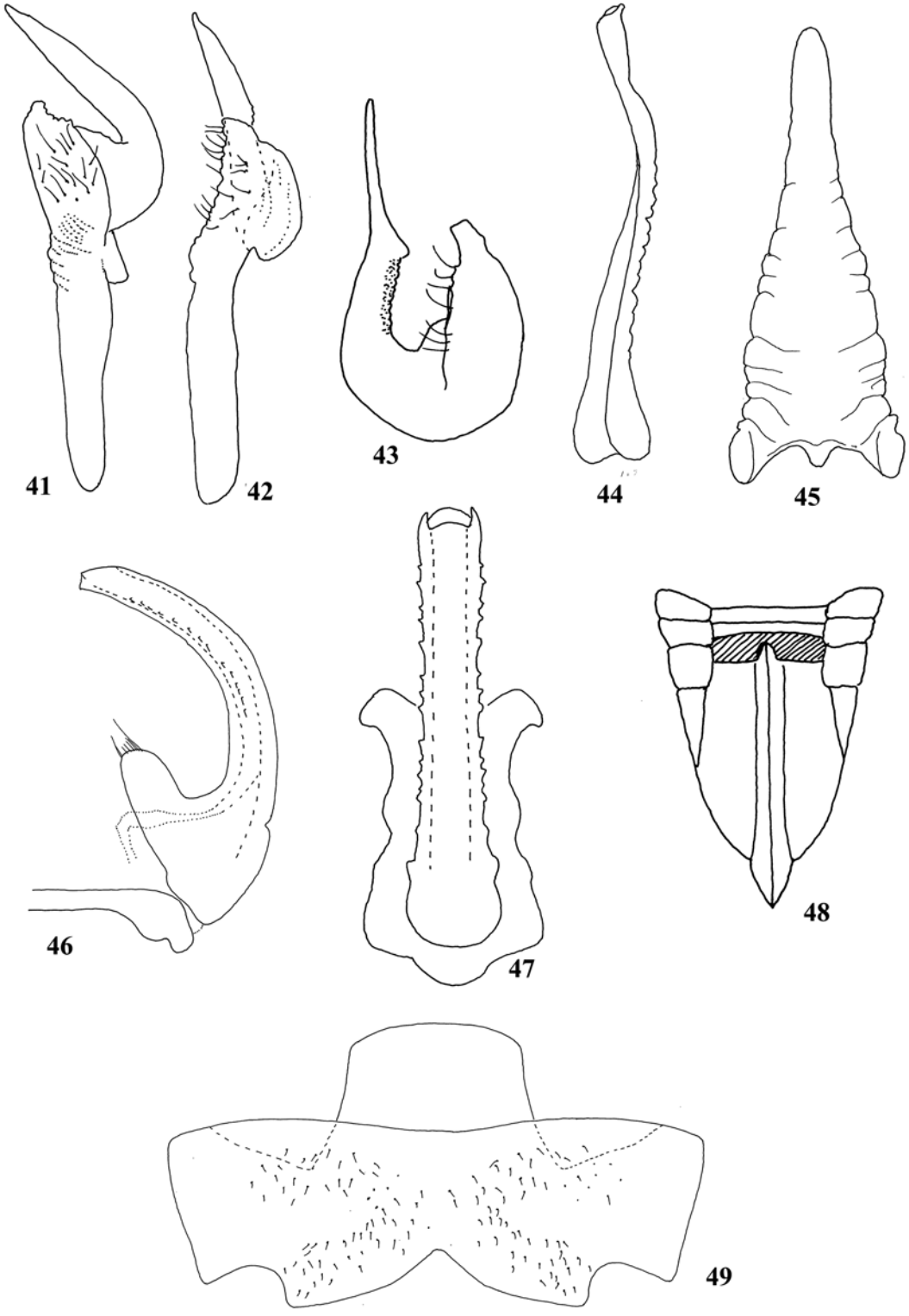
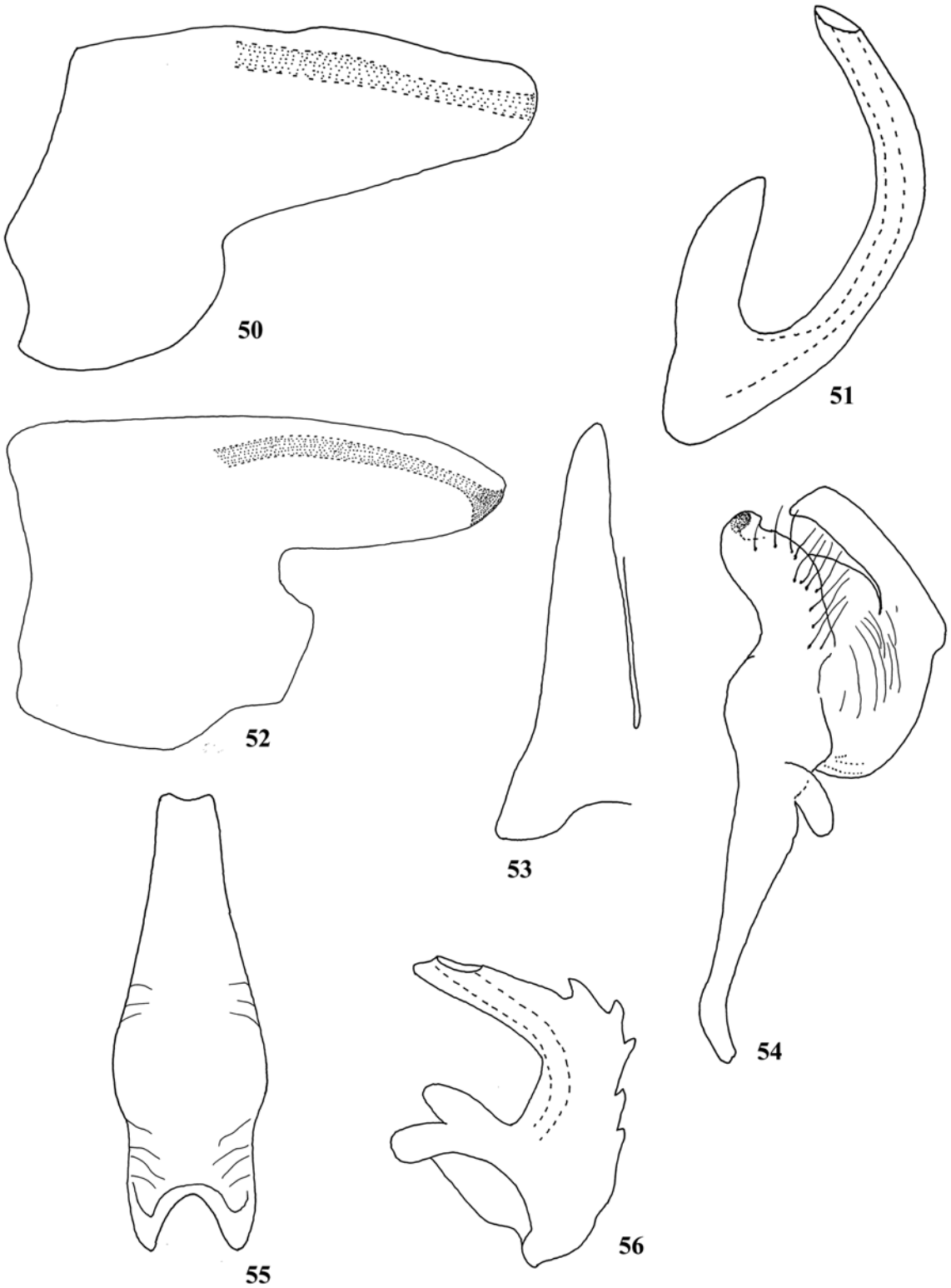


Fig.s 36-40. ***Assiuta omani*****: 36 - Chaetotaxy of fore femur, mesal view; 37 - Chaetotaxy of metabasitarsus, ventral view; 38 - Male genital capsule, lateral view; 39 - Male genital capsule, dorsal view; 40 - Male genital capsule, ventral view**



Figs. 41-49. ***Assiutao mani*****: 41 - 42. Male style, dorsal and lateral view, respectively; 43 - Apophysis of style, posterodorsal view; 44 - 45. Connective, lateral and dorsal views; 46.Aedeagus and part of connective, lateral view; 47 - Aedeagus posterodorsal view; 48 - Posterior part of female abdomen, ventral view; 49 - Female seventh and eighth sternites, ventral view.**



Figs 50-56. Species of *Assiuta*. 50-51. *Assiutacamena* Linnavuori: 50. Male pygofer, lateral view; 51.Aedeagus, lateral view. 52-56. *Assiutasalina* (Lindberg): 52. Male pygofer, lateral view; 53.Subgenital plate, ventral view; 54.Male style, dorsal view; 55.Connective, dorsal view; 56.Aedeagus, lateral view.

male with connective triangular and longer than aedeagus (Figs. 31, 45, 55)...Adelungiini

- Female first pair of valvulae with dorsoapical margin smooth; male with connective broad and much shorter than aedeagus, if longer than aedeagus (as in *Humpatagallia*), connective rod shaped ..... Agalliini

Emeljanov (1975) grouped the adelungiine genera into two groups, distinguishing the first group of genera (*Assiuta* and *Homogramma* Emeljanov) from the second group of genera (*Melicharella*, *Platyproctus* and *Pleopardus* Linnavuori) by the nature of the teeth on the second pair of valvulae and shape of the aedeagus. In *Assiuta* and *Homogramma* the second valvulae of the ovipositor has teeth in one uniform series ("uniform saw above"), on the other hand in the second group of genera (that includes *Platyproctus)*, the second valvulae of the ovipositor have teeth in two series set at apposing angles with different denticles ("two parts set at an angle to one another and with different denticles"). The aedeagal shaft was stated as flattened laterally in *Assiuta* and *Homogramma* but tubular in the second group but *A. omani* and *A. camena* have a flattened aedeagal shaft.

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Importance of hedgerows for wild bee abundance and richness in Kashmir Valley

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ABSTRACT: The investigations on value of various landscapes categories as a foraging habitat for wild bees were carried out in mosaics of small scale agriculture and natural vegetation areas of Kashmir valley during the spring seasons of year 2013 and 2014. In present study we tested the importance of habitat area, landscape composition and configuration on wild bees in valley. The habitats selected were hedgerows, agricultural fields, grasslands, and native woodland. We observed that bee differ in their response to many factors of landscapes. The hedgerows were attractive foraging habitat for native bees. The total species richness was highest in hedgerows. The overall bee faunas overlapped among habitats, bee assemblages in hedgerows were more similar to those in fields than to those woodlands. The flowering shrubs were important in attracting bees. Species richness and abundance of wild bees were surveyed on with independent gradients in local and landscape factors. Total wild bee richness was positively affected by complex landscape configuration, large habitat area and high habitat quality which provide them with assured nesting sites.

KEY WORDS: Hedgerows, Habitat, Bees, Wild, Ecology

INTRODUCTION

Insect pollinators are estimated to support 9.5% of world food production (Gallai *et al*., 2009) and wild bees have an important role in the delivery of this ecosystem service (Garibaldi, 2013). However, wild bees have undergone global declines (Woodcock *et al*., 2016) that have been linked to habitat loss and fragmentation, pathogens (Camerona *et al*., 2016), climate change and insecticides (Biesmeijer, 2006; Goulson *et al*., 2008; Ollerton *et al*., 2014; Potts, 2010; Winfree *et al*., 2009). Habitat degradations lead to severe decrease of bee abundance and richness in isolated semi-natural habitats (Krewenka *et al*., 2011). Agricultural landscapes are increasingly important settings for biological conservation, especially for the conservation of important pollinators such as bees of families Halictidae, Andrenidae, Bombus, Anthophoridae and Megachilidae (Jauker *et al*., 2012; Klein *et al*., 2007). Since, wild bees are the dominant providers of pollination services (Colla and Ratti, 2010) and research with a range of crops suggests that maintaining abundant and diverse native bee communities (Meiners, 2016) can provide insurance against the loss of pollination services in the face of reduced honeybee populations due to colony collapse disorder (CCD). The importance of wild bees to act as alternative pollinators for horticultural and agricultural crops is one reason to focus on their management and conservation in various

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landscapes. Therefore, the effective conservation of bee abundance, diversity and richness depends on understanding how their habitat requirements assured in different landscape categories (Jauker *et al*., 2012). Cultivated land are insufficient to provide various resources like, pollen, nectar, floral oils, nest sites, nesting materials and overwintering sites necessary to sustain local bee populations (Kremen *et al*., 2007). Since, the intensive cropped areas tend to lack floras and continuity of floral resources (Corbet, 1995), which are very important for the bees. The landscape from urban areas offers a potential refuge to different species (Samnegard, 2016). Cornelissen (2012) observed that between 13-40% of wild bee species living in urban settings, and the effects of hedgerows were known to restrict movement of some species (Kueûer *et al*., 2010). For the nesting sites of the wild bees, the hedgerows are important; however the pollen and nectar sources are not evenly distributed among the habitats (Westrich, 1996). Since, the flight ranges of the bees are limited, so they have to lie within their flight range for various requirements (Gathmann and Tscharntke, 2002). In present study the use of hedgerows with two corridors in south-eastern Kashmir, noted for high diversity of bees and flowering plants, was investigated.

MATERIALS AND METHODS

The Valley Kashmir is a temperate region and considerable area is under various fruit crops. During the survey in various locations the nests were observed mostly in barren, dry lands, irrigated, orchards and grass lands. Almost 15 % of the nests were located in plane areas and rest 85% on sloppy grounds. So, nest dominant areas were selected for the bee survey. Geographically Kashmir is stretched between 32^{o} 17^{-} to 37^{o} 60^{-} N latitude and 73^{o} 26^{-} to 80^{o} 30^{-} E longitudes. The mountain range in the Himalayas region varies in altitude 5,550 m on North-east dip down to about 2,770 m on South. Generally, the Kashmir contains the upper stages of the forest vegetation including pinus, populus, willow, rubenia and some other social forestry trees and lower stages of agricultural and horticultural crops including apple, pear, peach, plum, apricot, almond and cherry.

The Kashmir receives 25-35% and 50-60% of its precipitation during the winter and monsoon periods, respectively. The Budgam and Pulwama are largely characterised by agricultural landscapes with relatively small fields, less than 2.5 ha, and a mosaic pattern of habitat types with variable sizes. The hedgerows separated the fields. The forest areas are interspersed with areas of cultivated fields and hedgerows. On 10 locations we surveyed the hedgerows and agricultural fields for the abundance and diversity of wild bee species. We took 5 locations in south and 5 in north region for investigations. Generally, the agricultural fields were made up of contiguous farms. The field to field variations were minimized by standardised the farms into various habitat types having different management practices-like pesticide and fertilizer applications, mowing, grazing, ploughing etc. The crops like maize, oats, wheat, beans and brassica are common; however, the large areas in experimental sites are under paddy and considerable areas are irrigated pastures and mixed grass lands and forbs for cattle. On each farm, various types of social forestry tree were used to graze cattle for at least a part of year. There was no aerial application of any type of pesticide. In district Budgam walnut and almond orchards and in Pulwama the apple orchards were also surveyed for the bee species richness and abundance. The bees were surveyed in 10 habitat types and we establish the 30 transits in each category of landscape. Each transit of 2.5 m by 45 m rectangular plot, the maximum length of transits being constrained by length of hedgerows on some farms. All along the hedgerows we placed a transit and a second transit in an approximate centre of the adjacent field, running parallel to the largest dimension of the field. A third transit was placed randomly in nearest woodlot. The minimum distance between hedgerows and woodlot transits was 150m; however, the distance between hedgerows and fields transits were only 80 m. Based on the presence of dominant native perennial herbs, grasslands and economic shrubs, we identified the potential and important woodland sites which are probably the habitats for wild bees. The second transit were placed 250 m away from the woodland habitat. Normally, the minimum distance of native

and woodland transits were 350-650m away from agricultural fields.

Survey and Sampling

The timed periods of observations and hand-netting were used during investigations to sample, collect and assemblage the bees. During the investigations, the afternoon survey were also done, and completed between 9:00 am and 4:30 pm, and were only conducted in clear cloud free weather.

Two observers were used during the active flowering seasons of 2013-2014, observers alternated the transects they surveyed, and the order in which transects at a given site were surveyed. In each survey, the observer spent 45 min in the 40-45 meter transect area, catching and collecting the insect specimens and recording the flower species, if any, visited by each bee on the flowers or near the flowering plants. Generally, the stopwatch setting and handling time was not included in the observation time; the clock was turned off when a bee was caught and while it was being processed. The 45 min total observation time was divided into five 9-min periods (one for each subplot) in order to spread observer attention across the transect area. Data from the four subplots were combined to make one sample per transect, since the individual plots act as a replica, so data were pooled to get an average. During the survey, we caught all bees detected, or photographs were taken while foraging. Voucher specimens were deposited in pollinator lab of entomology, identified and preserved as per Schauff (1986), SKUAST-K, Srinagar.

Data analysis

For the comparison of the species richness among habitats we estimated total species richness for each habitat using Manitab and O.P.Sherom software, to determine the significance among the species pertaining to particular orders. The Student's t-test were used to compare the diversity and abundance of the bees captured from each habitat. One way ANOVA were used to compare the mean species richness and abundance among habitats, so that statistical comparisons of species richness and abundance were made among observations made in the same sampling periods. For estimation of dissimilarity, we calculated the Bray–Curtis index.

RESULTS

Species richness

Overall, we collected 687 bee individuals from all experimental locations during 2013 to 2014 (Table 1). The collection constitutes 20 bee species from 9 genera and 5 families. Generally, the sampling frequency varied among habitats, with a range of n = 75 to 120 samples (one sample equals one survey of one transect during one sampling period in 1 year). So roughly, 45-50 days were utilized for sampling the bee from different landscape categories. Therefore, to compare species richness among habitats, we randomly sub-sampled results of 65 surveys in each habitat. This analysis yielded a total of 16 species in fields, 18 species in hedgerows, 20 species in fruit orchards near hedge rows, 16 species in native woodland, and 13 species in woodlots. In total, 85-90% of the species recorded were common across different landscapes. In addition all of the species were recorded near by the stone fruit orchards on sloppy to plan areas of the valley.

For the given level of sampling effort (n), the hedgerows were observed to have highest estimated species richness and highest total population count with p-value, 0.0032 (i.e. statistically significant). The overall estimated species richness in fields, hedgerows, and native woodland also differ significantly. The species richness in woodlots was significantly lower than in the other three habitats. The flowering commences later at higher elevation, abundances of workers and male bees were also shifted later; therefore elevational comparisons play an important role in species richness (Pyke *et al.,* 2011), generally due of forage availability. Since, the observed species richness was highest in hedge rows near orchards, so jackknife estimates of actual species richness were highest for hedgerows with (J) 1st order: 19 species, 2nd order: 20 species so on. Among the all species observed the species

Table 1. Wild bee species richness and overall mean abundance (bees/m²/10min.) on three stone fruit crops in Kashmir valley during 2013-2014

S. No	*Species*	Peach (*Prunus persica*)	Plum (*P. domestica*)	Cherry (*P. avium*)	Mean abundance
1	*Lasioglossum marginatum* Brulle	4.23	4.73	5.35	4.77±0.23
2	*L. regolatum*	3.00	3.00	4.11	3.37±0.29
3	*L. himalayense* Bingham	3.94	4.22	4.63	4.26±0.39
4	*L. sublaterale* Blüthgen	2.84	2.33	4.00	3.05±0.02
5	*L. leucozonium* Schrank	2.45	2.00	3.87	2.77±0.12
6	*L. nursei* Blüthgen	4.00	3.00	4.59	3.86±0.11
7	*L. polyctor* Bingham	2.39	1.33	3.20	2.30±0.41
8	*Halictus constructus*	1.34	1.00	3.03	1.79±0.01
9	*Sphecodes tantalus* Nurse	0.00	0.34	2.05	0.79±0.04
10	*Andrena patella* Nurse	1.50	0.88	2.26	1.54±0.19
11	*A. flordula*	0.89	0.66	1.53	1.02±0.14
12	*A. cineraria* Linnaeus	0.34	1.33	1.20	0.95±0.03
13	*A.bicolor* Fabricius	0.44	0.00	0.48	0.30±0.05
14	*A. barbilabris* Kirby	0.00	0.00	0.17	0.05±0.07
15	*Amegilla cingulata* Fabricius	0.733	0.44	0.97	0.71±0.22
16	*Megachile rotundata* Fabricius	0.77	0.67	1.17	0.87±0.31
17	*Anthedium conciliatum* Fabricius	0.73	0.11	0.74	0.52±0.03
18	*Xylocopa valga* Gerstaecker	1.11	0.34	1.03	0.82±0.01
19	*X. violacea* Linnaeus	0.73	0.39	1.05	0.72±0.00
20	*Bombus* spp. Litreille	0.05	0.00	0.01	0.02±0.01
	N=20	N=18	N=17	N=20	-
	Total samples	199	167	321	387

of family Halictidae were most dominant. Among the Halictidae family the genus *Lasioglossum* was the most abundant and dominant flower visitor, representing 46 to 48.01% of all individuals collected during surveys. Among these wild bees the species *L. marginatum* was the most abundant species (Fig. 1). The foraging ranges of this species were nearly 100 m from the nesting habitat. The cherry *Prunus avium* recorded the highest of relative abundance and peach *Prunus persica* recorded comparatively less. On stone fruit (peach, plum and cherry) flowers from three districts (Ex. Locations), the mean relative abundance of species were significantly highest of 4.77±0.23 (t=4.21, t. stat. =2.31, p.value <0.01) and comparatively lowest 0.02±0.01 pollinators/m²/10 min. (t= 7.30, t. stat= 1.94, p.value < 0.01) with ANOVA for pooled relative abundance of pollinators/m²/10 min. (F. ratio 0.81; CV, 13.04; SE, 0.77; $CD_{(0.05)}$= 0.43; Pearson's correlation= 0.79, T-test=4.03,p.value < 0.001). The mean relative abundance of genus *Lasioglossum* Curtis on three stone fruit crops were in order viz. *L.marginatum*> *L.nursei*> *L.Himalayans*> *L.regolatum*> *L.sublaterale*> *L.leucozoni*> *L. polyctor* (Fig. 1). On all three crops the the relative abundance of *Halictus constructus* were comparatively minimum. While as, on all the three crops, the species of genus Andrena has the relative abundance in order viz. *Andrena patella*> *A. flordula*> *A. Cineraria*> *A.bicolour*. In family Apidae the species *Xylocopa valga* maximum and *Xylocopa violacea* showed minimum of the mean abundance during both years of studies. The species *Megachile rotundata* and *Anthedium consolatum*

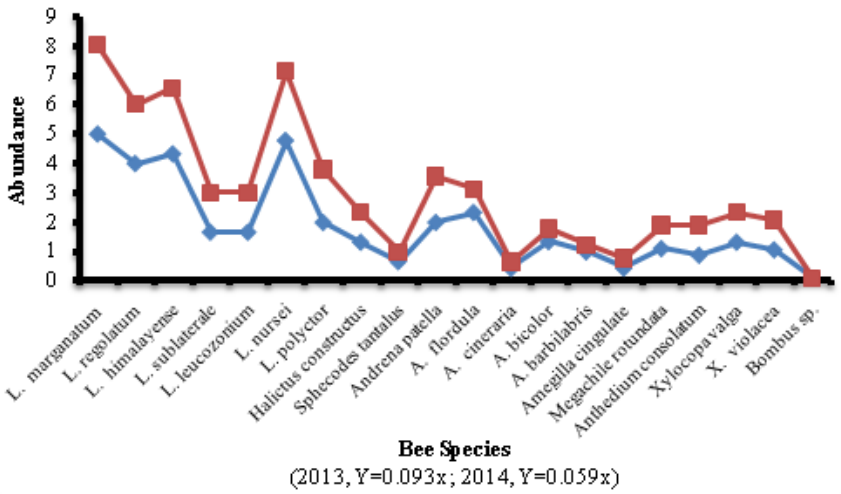

Fig.1 Relative bee abundance of stone fruit (*Prunus persica, P. avium, P. domestica*) crops in Kashmir during 2013-2014.

of family Megachilidae also showed less relative abundance during investigations. Overall, the species richness was more on *Prunes avium* compared to *P. persica* and *P.domestica* (Table 1).

Species composition and overlap

The cumulative bee faunas of the fields, hedgerows (orchards), woodlots, and native woodland overlapped. The species composition from hedgerows were overlapped and sheared with other habitat categories. Nearly, 61-62% species from hedgerows also occurred in fields during both years of studies.

Likewise, 48-49% species also occurred in woodlands, and 70-71% in native woodlands. In hedgerows, about 7.21-7.33% of bee species were found exclusively. The fields, woodlots and woodlands shared the majority of the species present there with other habitats, and had small number of unique species. We compared the bee assemblages at the transit level- summing the abundance of the bee species occurring on a given transecting the pre, early and late monsoon over the period of two years. Strongest differences were between fields and each of the hedgerows, which are mainly occupied by orchards, woodlots and native woodlands. Studies showed that the hedgerows were significantly more similar to woodlots and native woodland than to assemblages in agricultural fields and grass lands. Among the transects and within habitats a considerable variation were recorded in bee assemblage and also a wide overlap in species composition among habitats were found.

Spatial analysis and spatial autocorrelation

In various experimental locations, the huge data tables of bee specimens obtained from censuses and surveys were analyzed to extract the main trends in bee abundance and species composition across many habitats. The autocorrelation statistics measure and analyzed the degree of dependency of bee composition on various habitats. It measuring a spatial bee abundance matrix that reflects the intensity and suitability of the habitat and its relationship with the bee species. e.g., the abundance of the forage, distance from nesting habitat, anthropogenic pressure, and aspect of the habitat with respect to sun. From the dataset of cumulative bee assemblages, summing bee abundance data for each transect across all sampling periods in 2013 and 2014, to test for one way ANOVA in bee species composition. Sample sizes in this dataset are lower than the total number of transects surveyed, as only those transects that had been in four of six sampling periods, and a minimum of three species in their cumulative bee assemblages, were included in the analysis. T-test

showed a statistically significant (t. test<0.05%), though relatively weak. This result was apparently primarily due to correlation among native woodland transects along the Pulwama and Budgam districts.

Abundance and species richness *vs* sampling periods

The patterns of the bee abundance were variable across 2013-2014. Generally, the abundance was highest in 2013 and lowest in 2014. Current study showed that bee abundance was highly variable among transects within habitats. There were some consistent patterns; however, bee abundance in hedgerows peaked in the pre-monsoon, declined in the early monsoon, and then increased slightly in the late monsoon. During the pre-monsoon period, fields and hedgerows tended to have higher abundance than either native woodland or woodlots. Bee species richness was also variable within habitats, and there were few significant differences among habitats.

During the year 2013, the pre-monsoon species richness was highest in hedgerows compared to 2014. Since, the valley of Kashmir was hit by floods and various foraging habits were affected so bee assemblage and abundance were low during 2014. During the early moon soon the fields tended to have the most species per transect compared to other habitats. Generally, the woodlots had the lowest mean species richness in most sampling periods. Habitats varied in the pollen specialist species, and hedgerows attracted a relatively large number of specialists- more than both fields and native woodland. Conducting the equal sampling frequency efforts in all habitats, the highest number of specialist species were in order; hedgerows>fields>native woodlands>woodlots (Fig.2).

DISCUSSION

The various landscape categories like, fields, grasslands, meadows, pastures, roadsides, hedgerows, edges, and wild barren lands can be managed to provide important habitats for wild bees. However, in current study, the hedgerows acted as net exporters of bees into adjacent fields. Sydenham *et al.* (2016) and Brosi and Ehrlich (2016) observed that hedgerows acted as an export for bees in landscapes. The study showed that hedgerow creation may be essential for enhancing native pollinator abundance and diversity and for pollination services to adjacent crops**.** Semi natural grasslands provide important habitats for bees, but are often lost due to changes in land use, particularly reduced livestock grazing (Murray *et al*., 2012; Stoate *et al*., 2009). The anthropogenic landscape elements, such as power line clearings, hedgerows (Morandin and Kremen, 2013), and orchard field edges (Sydenham et al., 2016), may also provide important habitats for bees in the agricultural landscape matrix. In Budgam and Pulwama, the mixed farm and natural landscapes contribute to available foraging habitat for local native bee populations.

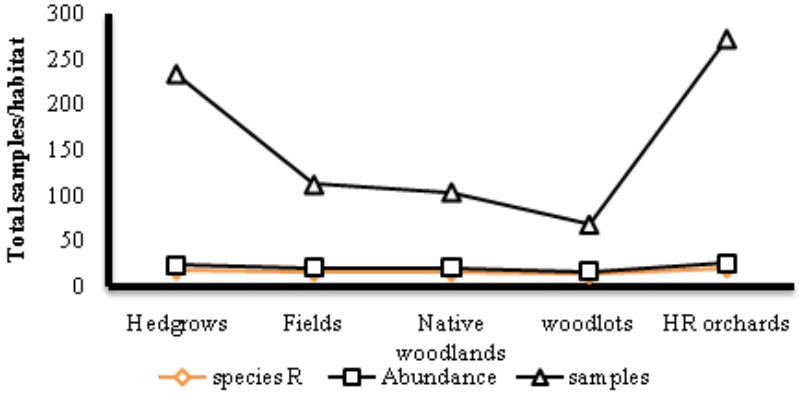

Fig.2 Population abundance and total bee samples collected from various habitats during 2013-2014 in Kashmir valley

The survey of two years showed that diverse assemblages of bees are finding nectar and pollen resources in hedgerows and a total of 20 bee species from 9 genera and 5 families were observed in hedgerow visiting various flowers for nectar and pollen. Due to the extreme temporal variability in native bee faunas, it is important to look at habitat use by season, not just in assemblage. During 2013 and 2014 the hedgerows were arguably the best foraging habitat for bees, and attracted more diverse bee assemblages than fields, woodlots or native woodland. The flora of dominant tree, native woodland and shrubs attracting majority of native bees foraging in hedgerows in pre-monsoon. The trend was apparent in both years of the study, but only statistically significant in 1 year; the non-significant difference in 2014, which is mainly due to floods in valley, caused the drop in floral availability in among the transects in both hedgerows and fields. Hedgerows bloom and so provide food for insects. Current study showed that native wild plants, shrubs and trees within hedgerows provide important foraging resources for wild bees and managed honey bees. During the pre-monsoon periods (2013 and 2014), the agricultural fields and hedgerows were better foraging habitats, with higher bee abundance and species richness, than either woodlots or native woodland. During the year, 2013, the fields attracted bees in higher or comparable numbers to hedgerows during the pre-monsoon and also in later sampling periods. However, in European, both hedges and fields were equally attractive to wild bees for at least some seasons. The bumblebees in agricultural habitats find much higher numbers foraging in the herbaceous understories of hedgerows than in adjacent fields (Croxton *et al*., 2002). Under Kashmir conditions, the pasture and hay crop fields generally supported perennial and annual flowering weeds. The available forage is extended by irrigation of the fields, and the increase the foraging periods for the bees beyond that of natural habitats, since, the available flower resources are tied to seasonal rains during spring and summer seasons. This expanded blooming period could boost the total bee species richness observed in fields. Research showed a greater total species richness in agricultural habitats than in native forest (Meiners, 2016). But, surprisingly, the patterns of bee species richness were found opposite to one we observed. Since the species and abundance of bees were less in wood woodlands so it was mainly due to absence of the early and late flowering periods, with no flowers.

We observed that the healthy and managed hedgerows are home to a rich plant community, and provide crucial bee habitat same were earlier confirmed by Monkman (2013). The hedgerow shrubs such as cherries, plants of family rosacea and wild apple trees are a reliable and plentiful source of nectar and pollen in May and June, a time of year when many other plants have not yet flowered. The hedgerows appeared to offer additional resources for native bee species that were also using other agricultural and natural habitats in the landscape. The hedgerows comparatively provide the forage for much time of the year. The hedgerows shared 87-90% of their bee species with at least one other habitat. During the sampling periods, the dispersed pattern of bee species distribution among hedgerows and other available habitats was more evident in each habitat. Similarly, the USA New Jersey similar pattern of wide overlap in the bee faunas of agriculture and native forest were observed (Meiners, 2016). During the current investigations, a relatively small proportion of species occurring in agricultural or forest habitat were unique. Same were earlier reported by Winfree *et al.* (2009) from USA. Due to the close overlap of the many proximal habitats, the broad overlaps in bee faunas were observed. The typical bee foraging distances are estimated at 150 m to more than 1.55 km, and multiple agricultural and natural habitats are often available within a radius of 500 m to 1 km, well within the flight ranges of many native bee species like Bumble bees and Andrena. However, the flight ranges of the most Halictidae were only 150-210 m from nesting site. The foraging behaviour of wild bee species may also explain their wide distributional pattern among available habitats on and off farms. Since, the multiple habitats were utilised or visited by solitary bees to gather the resources they require, build their nests, foraging for resources and to track patchy and ephemeral floral resources.

During the current study, in intensive cultivated farm fields there was low field diversity (lack of hedgerows), and bee abundance and diversity were lowest; which was also confirmed by Venturini *et al*. (2017) that insect pollination reservoirs may offer growers a practical tool for increasing wild bee populations and decreasing reliance on managed bees. The factors such as effectiveness, reservoir-to-crop ratios, and costs and benefits are important in particular habitat. Further the relevant aspect includes plant-pollinator relationships, landscape context, wild bees as pollinators, flower selection, and limitations. Recent research clearly suggests that pollination reservoirs can increase wild bee populations, crop yield, and profit. However, due to dominance and abundance of the resources in hedgerows, it shared the majority of their bee fauna with other habitats, and attracted some native bee species that were otherwise uncommon in the other habitats. In the hedgerows, the floral diversity was higher so were the unique floral cues which attracted the major and uncommon bee species. Among the species sheared, the most abundant examples were the species of genus Lasioglossum of family Halictidae (Dar, 2016). Overall, the higher population of the bees were attracted and stimulated by hedgerows than other habitats. More specifically, the members of family Andrenidae were dominant in the hedgerows and were uncommon in other habitats.

The Lasioglossum species preferentially visited the flowers of a native shrub, agricultural crops and fruit plants like stone fruits (Dar *et al*., 2017a; Dar *et al*., 2017b). Hedgerows may indirectly contribute to local bee diversity by providing forage to an assemblage of native bee species that vary widely in foraging ecology and seasonal activity period. Further the bee fauna in hedgerows included some species that are generalists in both habitat use and pollen collection.

Trait-Specific Responses

Since, the land-use intensification and loss of semi-natural habitats have induced a severe decline of bee diversity in agricultural landscapes (Dar *et al*., 2017c). The hedgerows are among the most important bee habitats in temperate areas, but they are threatened by decreasing habitat area and quality, and by homogenization of the surrounding landscape affecting both landscape composition and configuration. In present study we tested the importance of habitat area and quality as well as landscape composition and configuration on wild bees in Kashmir valley. We hypothesised that bees with different traits might differ in their response to the tested factors of landscapes. Species richness and abundance of wild bees were surveyed on with independent gradients in local and landscape factors. Total wild bee richness was positively affected by complex landscape configuration, large habitat area and high habitat qualities (i.e. steep slopes) which also provide them with assured nesting sites e.g. *A. Cineraria* (Dar *et al*., 2017d). Sphecodes bee richness was positively affected by complex landscape configuration and large habitat area; whereas, habitat specialists, e.g. Bumble bee assumed in current studies, were only affected by the local factors, habitat area and habitat quality. Small social generalists (*Andrena* spp.) were influenced by habitat area (Dar, 2016). Our results emphasize a strong dependence of habitat specialists on local habitat characteristics. We conclude that a combination of large high-quality patches and heterogeneous landscapes maintains high bee species richness and communities with diverse trait composition. Such diverse communities might stabilize pollination services provided to fruit crops and wild plants on local and landscape scales, since pollinators exhibit the trait specific response to the habitat disturbances in the landscapes (Bommarco *et al*., 2010; Hopfenmuller *et al*., 2014; Goulson *et al*., 2008; Ockinger *et al*., 2012).

Hedgerows were observed to have value as habitat for bees. It can also be a refuge for pollinators. The management of habitats for pollinators have a significant impact on bee conservation. The hedgerows include a diversity of native wild-flowers with overlapping bloom times, to provide forage for pollinators throughout the growing season. Landscape categories can be of great benefit to bees. Best management practices include consideration of timing and frequency of mowing, spot spraying rather than broadcast use of

herbicides, and surveys to identify existing habitat that provides native plant resources for wild bees. The habitat managers must develop a management strategy that addresses safety concerns while also benefiting the wildlife such as bees.

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Biocontrol potential of *Heterorhabditis indica* against the maggot of *Bactrocera cucurbitae* (Diptera:Tephritidae)

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ABSTRACT: Studies conducted to determine the pathogenic efficiency and bio-control potential of the entomopathogenic nematode *Heterorhabditis indica* against melon fruit fly *Bactrocera cucurbitae* showed dose-dependent and time dependant effect. The 24 h LD_{50} value of *H. indica* was 50.28 and that at 48h was considerably reduced (38.17). Highest mortality was observed @ 160 IJs/ maggot in the bioassay. In field trials also, *H indica* successfully reduced pest population. A higher mortality of 65% was realized when the parasite was used @ 400,000 in 100 ml of aqua suspension. The present study confirms the susceptibility of *B. cucurbitae* against *H. indica* under laboratory and field conditions. © 2017 Association for Advancement of Entomology

KEYWORDS: *Bactrocera cucurbitae, Heterorhabditis indica,*cucurbits, infective juveniles, biological control.

Fruit flies are the most damaging insect pests of Cucurbits. There are about 325 species of fruit flies occurring in the Indian subcontinent of which 205 are from India alone (Kapoor, 2005). *Bactrocera cucurbitae* and *B. ciliatus* are the two most common fruit flies in India (David and Kumaraswami, 1996; Singh and Sachan, 2010). The melon fruit fly, *B. cucurbitae* (Coquillett) (Diptera: Tephritidae) is a very serious pest found in temperate, tropical and subtropical regions including Kerala, infesting cucurbit vegetables and the crop loss varies between 30-100% (Dhillon *et al*., 2005; Kapoor, 1993).

Rhabditid nematodes of the families Steinernematidae and Heterorhabditidae are entomopathogenic nematodes that are pathogenic to a wide range of agriculturally important pests and successfully used as alternatives to chemical insecticides (Gaugler and Kaya, 1990; Forst and Clarke, 2002). Biocontrol efficiency of *H. indica* against various lepidopteran pests have been studied extensively for green house and nursery crops (Jagdale, 2013; Lacey and Georgis, 2012). The IJs of *H. indica* harbour symbiotic gut bacteria, *Photorhabdus luminescence* (Boemare, 2002) which is lethal to a wide range of insect hosts. There is a dearth of information on the effective control of the melon fruit fly *B. cucurbitae* using entomopathogenic nematodes. The present study is an attempt to fill this gap and assess the susceptibility of *B. cucurbitae* to *H. indica* .

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Starter cultures of *H. indica* and the greater wax moth, *Galleria mellonella* were procured from the Central Plantation Crops Research Institute (CPCRI), Kayamkulam, Alleppy, Kerala. *Heterorhabditis indica* was cultured *in vivo* using the last instar larvae of *G. mellonella* (Woodring and Kaya, 1988) at room temperature (28°-32°C). Emerging IJs were harvested through modified White trap method (White, 1927) within 24h and stored in open Petri dishes as aqua suspension. The nematode suspension was aerated using filler and the water level was maintained to aid survival during storage. Different concentrations were prepared by serial dilution of the suspension and counting of nematodes was done using a micro pipette (Vertex) and a stereo microscope (Labomed CZM 2). *Galleria mellonella* culture was maintained using three types of culture chambers- mating, rearing and pupal (sterilized 4- liter plastic cages) in the laboratory and the larvae were fed with an artificial diet (Singh, 1994). Fully grown last instar larvae were used for EPN culture.

The duration of the study was for two years (September 2014 to August 2016) and the experiment was conducted in a model field of 4 cents located in the campus of Fatima Mata National College, Kollam, Kerala (8° 53' 35.56" N and 76° 36' 50.9" E). Host plants chosen for the study were *Momordica charantia,* the bitter gourd and *Trichosanthes cucumerina,* the snake gourd. Seeds of known varieties (Preethi and Kaumudi) were purchased from the Regional Agriculture Research Station (RARS), Vellayani, Thiruvananthapuram, Kerala. Ripe yellowish–orange infested fruits were collected from the field and incubated in the laboratory in clean, dry and sterilized 3-liter plastic bottles for rearing *B. cucurbitae*. Mouth of the bottles were covered using band aid cloth and tightened with rubber bands. The last instar maggot- the only larval instar that came out of the fruits were transferred to separate rearing bottle and a quarter of its bottom area was provided with soil (20gm) for pupation. Emerging adults were transferred to fresh bottles containing fruit pieces. To avoid starvation during early hours of emergence, adults were provided with honey placed on cotton balls. Fruits infected with eggs were placed in rearing bottles till the emergence of last instar maggots.

Late third instar maggots of *B. cucurbitae* were used for the laboratory bioassay employing filter paper exposure method of Woodring and Kaya (1988). Petri plates of 10 cm diameter were floored with Whatman No.1 filter paper and in each plate, 1 ml of the EPN suspension was dispensed equally onto the filter paper and 10 maggots were introduced. Sixteen treatments ranging from 100 IJs/ml (10 IJs/ instar) and progressing in multiples of 100 were prepared for the laboratory bioassay. Each treatment with ten replicates and a control (11 sets) containing 10 maggots in each set were studied. Observations were made at 24h and 48h post inoculation. Field trials were carried out in randomized block design in soil and the field was randomly plotted into 20×20×5 cm size soil plots. Five treatments including a control, with six replications each were carried out. Each replication was with 3 plots. Doses @ 100 000 IJs, 200 000 IJs, 300 000 IJs and 400 000 IJs in 100 ml aqua suspension were prepared by serial dilution using well water. Control plots were treated with 100 ml well water. EPN suspension was applied using a hand sprayer 10-12 hours before maggots fell on the ground. Four days after nematode application, the soil was collected and carefully observed for pupae. Numerical density of the infected and uninfected pupae were recorded. Laboratory bioassay data of dosage mortality relationship was subjected to Probit analysis (Finney, 1971) using the software SPSS version 16 to determine 24h and 48h LD_{50} and LD_{90} values. Percentage of infection in the field was subjected to analysis of variance (ANOVA) and significance was calculated at 5% level.

Inoculation of *H. indica* revealed successful infection. Purple colour of third instar maggots of *B. cucurbitae* signalled its susceptibility to the nematode. Mortality rate was directly proportional to numerical density of the nematode and 100% mortality was observed within 48h @ 160 IJs/ instar. Infected maggots became inactive and died within 24 to 48h. Early cadavers appeared bright purple in color (Fig.1) and later turned dark brown.

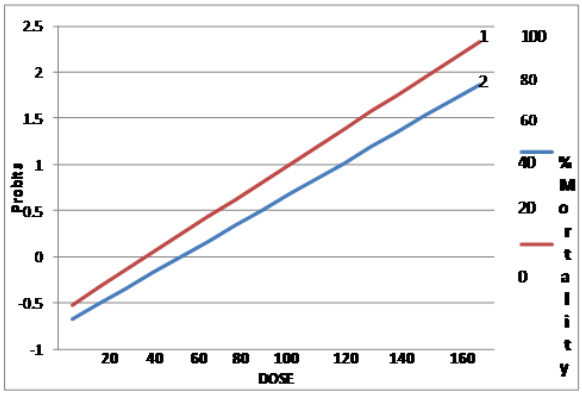
Fig. 1 Maggots - Before and after inoculation

Fig. 2 White trapped cadavers of maggots

Cadavers subjected to White's trap (Fig.2) resulted in emergence of EPNs and the cause of infection was confirmed. Newly emerged nematodes collected and preserved as aqua suspension in double distilled water always lived more than 5 days.

Mean percentage mortality of the third instar maggots of *B. cucurbitae* at different concentrations of *H. indica* is given in Fig.3. A significant decrease in the LD_{50} and LD_{90} values (38.17 and 107.04 respectively) was found at 48h than that at 24h (50.28 and 125.95 respectively) showing that mortality increased with exposure time. The Chi Square values, regression equation, 24h and 48h LD_{50} and LD_{90} values and the fiducial limits are presented in Table 1. More number of individuals (100) and treatments (16) were employed in the present study and the data obtained was highly significant. It was also observed that the doses applied were highly effective and relevant for the bio-control process. Median lethal dosage was high at 24h (50.28) and low at 48h (38.17), indicating a significantly higher mortality at 48h ($P< 0.05$). This revealed a higher susceptibility of *B. cucurbitae* at 48h exposure to *H. indica* and the virulence exhibited by the nematode increased with exposure time. Thus mortality was dose and time dependant.

Studies on the pathogenecity of *H. indica* in the field (Fig. 4) against the late third instar maggot of



1 = 48h, 2 = 24h

Fig. 3 Log Probit Curve of mean percentage mortality of III instar maggot of *B. cucurbitae* at different concentrations of *H. indica*

B. cucurbitae before pupation resulted in an increase in mortality with increasing dose. As the third instar maggot pupated soon after it entered the soil, only infected pupae could be observed in the soil after field trials (Fig. 5). The mortality of the maggots was found to be the same as the number of infected pupae. The data recorded 4days after treatment (DAT) revealed that the infection of the pupae varied from 12.73 (T_2) to 65.36% (T_5). Considerable increase in mortality was observed from T_2 (d) to T_3 (c) and T_4 (b) to T_5 (a) than that between T_3 and T_4. T_5 (a) was significantly more effective than the other treatments and recorded a maximum of 65.36 % infection to the pupae. Infection and mortality was in the order $T_5>T_4>T_3>T_2$ (Table 2).

Fig.4 Experimental field

Fig.5 Infected pupae in the field

Table 1. Probit analysis of dosage mortality relationship of III instar maggot of *B. cucurbitae* by *H. indica*

Time	Heterogeneity		Regression Equation (Y)= a+bX	LD_{50}	LD_{90}	Fiducial Limit	
	Chi-Square	Df				Lower	Upper
24 h..	5.47	14	0.017 X - 0.852	50.28	125.95	45.27	54.82
48 h..	1.96	14	0.019 X - 0.710	38.17	107.04	32.90	42.83

Chi-Square Table Value ($P < 0.05$) = 23.68.

Table 2. Evaluation of *H. indica* against the third instar maggot of *B. cucurbitae* (4 DAT) in the field

Treatments	Dose (IJs/100ml)	% Mortality(4 DAT)*	Range
T_1	0	1.11 (1.125) ** e	0 - 3.57
T_2	100, 000	12.73 (3.609) d	9.0 - 17.6
T_3	200, 000	32.83 (5.734) c	25.0 - 48.2
T_4	300, 000	46.93 (6.866) b	38.0 - 58.3
T_5	400,000	65.36 (8.108) a	57.8 - 73.9
CD at 5% - 0.717			

* DAT – Days after treatment.: ** Figures in parenthesis are square root transformed values.

Laboratory bioassay studies of Supekar and Mohite (2013) and Maneesakorn *et al.* (2010) revealed the efficacy of *H. indica* against *Pappillia japonica* and *Holotrichia serrata* Fab. respectively. Divya *et al.* (2010), Sankar (2009) and Garcia *et al.* (2008) employed higher doses of *H. indica* than the present study to obtain maximum mortality. Third instar larvae of the diamond black moth (DBM) of cabbage, *Plutella xylostella* showed 96% mortality when infected by *H. indica* within 72h of application. The proportion of DBM mortality increased with increased exposure time (Nyasani *et al.,* 2008). In our study also mortality increased when exposure time increased from 24h to 48h and mortality was proportional to dose and time. Though the final instar maggots of *B. cucurbitae* were small in size, high dose of IJs was required for higher mortality. This can be attributed to the shape of the body (elongated) and dynamic movements (folding and jumping) of the maggots.

Green house pot culture experiments conducted by Bharati and Mohite (2014) revealed that application of 450 IJs ml^{-1} of *H. indica* were very effective in controlling second instar grub of *Leucopholis lepidophora* (Blanchard) and recorded 45.33 to 87.60 per cent grub mortality at 15 DAT. Cotton plants, *Gossypium herbaceum* sprayed with *H. indica* at a dose of 1000 IJs ml^{-1} against various larval instars of *Helicoverpa armigera* and *Spodoptera litura* under green house study revealed increased percentage of mortality with increasing age of larva and duration of exposure (Divya *et al.*, 2010). Results of the current investigation also showed a similar trend. The present study confirms the possibility of *H. indica* as an effective biocontrol agent of *B. cucurbitae*.

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First record of G*onolabis electa* Burr, 1910 (Dermaptera: Anisolabididae) from India

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ABSTRACT: *Gonolabis electa* Burr, a small earwig is reported for the first time from India. This species is widely distributed in the Oriental Region and adventives to Ethiopian Region but not recorded so far from India.

KEY WORDS: *Gonolabis electa*, earwig, Oriental Region, India

Dermaptera (earwigs) is a polyneopteran insect order with about 2200 described species mainly from tropical and warm temperate regions (Popham, 2000; Grimaldi and Engel, 2005; Haas *et al.*, 2012). The dermapteran fauna of India has been studied intensively and were recorded 315 species by Srivastava (1988, 2003 and 2013). Further, Lal and Hegde (2012) described a new species *Euborellia nainitalensis* from Nainital, Uttarakhand. The present report adds an additional record to India. Several studies have proved that earwigs act as pests and at the same time they are beneficial also. They are pests in gardens and agricultural fields in many cases, which often feed on pollen grains, petals, tender foliage and shoots causing damage to the plants. *Euborellia stali* (Dohrn) has been observed to bore into the tender pods of groundnut (*Arachis hypogaea*) and feeds on its kernels (Cherian and Basheer, 1940). Earwigs act as 'scavangers' of the nature as these are omnivorous and protect our environment by consuming dead and decaying insects, fruits and vegetables etc. In certain cases, earwigs are also considered as valuable bio control agents for crop pests, consuming armyworms, aphids, mites, scale insects, sugarcane rootstock borers and tropical corn borers.

The genus *Gonolabis* Burr belongs to the family Anisolabididae. It is distributed in the Oriental, Australian and Ethiopian Regions (Srivastava, 2003). There are nine species reported under the genus from India. The species *G. analia* (Ramamurthy & David), *G. emarginata* (Ramamurthy & David), *G. nilgiriensis* (Srivastava), *G. penicillata* (Borelli), *G. punctata* (Srivastava) and *G. sisera* (Burr) are known from Tamil Nadu; *G. burri* (Srivastava) is known from Maharashtra and *G. krishnappai* Srivastava from Karnataka. Srivastava (2003) stated that, *G. electa* is widely distributed in the Oriental Region and adventives to Ethiopian Region but not recorded so far from India. The genus *Gonolabis* is defined by the following characters: size small to large (7.5 to

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Fig. 1 ***Gonolabis electa*** **-male**

Fig.2 ***Gonolabis electa*** **-female**

23.5mm); apterous or with elytra abbreviated in various shapes; eyes shorter than the postocular area; abdomen gradually enlarging posteriorly, attaining maximum width at ultimate tergite or spindle shaped; forceps short arcuate or long and slender, contiguous or subcontiguous near base, gently incurved apically.

Material examined: INDIA: Kerala: Ponmudi, Thiruvananthapuram district, 15.x.2012, K.G.Emiliyamma, 1Male, 1Female, Registration No. ZSI/WGRC/IR-INV- 4533.

Measurements:

Length of body:	Male: 8.2	Female: 8.1
Length of forceps:	Male: 1.4	Female: 1.6

Diagnostic characters: Male(Fig. 1): Body colour reddish brown to black; antennae dark brown or lighter in colour; basal segment sometimes yellow; sides of pronotum and legs yellow, femora darker. Head broader than long, frons convex, sutures indistinct, hind margin slightly emarginate in middle posteriorly; eyes shorter than postocular area; antennae 15 segmented; 1st segment stout, slightly expanded apically, shorter than the distance between antennal bases; 2nd short; 3rd long and cylindrical; 4th elongated, shorter than 3rd; 5th cylindrical, almost equal to 3rd, remaining segments gradually increasing in length and becoming thin; pronotum as long as broad, quadrate, slightly widened posteriorly, all margins straight; prozona slightly convex and indistinctly separated from metazona, median sulcus weakly marked; apterous; mesonotum with hind margin straight and metanotum emarginate posteriorly; legs with 1st segment of hind tarsi is equal to the combined length of 2nd and 3rd; abdomen narrowed at base, gradually increasing in width posteriorly and attaining maximum width at 9th tergite, the surface above of 9th tergite punctulated, weakly convex, sides of segments acute angled posteriorly; penultimate sternite rounded posteriorly, narrowly emarginate in middle; ultimate tergite broader than long, almost smooth, sometimes with one or two rows of punctulations, weakly raised on either side of middle line, median sulcus distinct, laterally with a short, oblique carina, hind margin in middle almost straight, oblique above the base of forceps; forceps with branches remote at base, short, arcuate, trigonal above in basal one-third, afterwards depressed, internally serrated. **Female (Fig. 2):** Resembles male in all characters, except the ultimate tergite narrowed posteriorly; penultimate sternite convex posteriorly in middle; forceps simple and straight.

Remarks: The studied specimens are exactly similar to the descriptions of Srivastava (2003), except for the following characters: body brownish black; 2nd segment of antenna yellowish brown; 4th and 5th segments of antennae equal in length; the length of 1st tarsal segment is longer than the combined length of 2nd and 3rd tarsal segments; ultimate tergite with one row of punctulation.

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Screening of snake gourd genotypes for low infestation against semilooper, *Anadevidia peponis* F. (Lepitoptera: Noctuidae)

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ABSTRACT: Fifty snake gourd genotypes were evaluated to screen for low infestation against semilooper during 2011-2012 under field condition. The low infestation of semilooper was observed in Kulithalai local short, Kumbakonam local short, Kumbakonam local long, Madurai local long and PKM-1 types (43 to 49.70 larvae per vine). While the genotypes *viz*., IC418478, IC411877, IC411878 and IC410160 recorded a higher semilooper infestation (91.0, 84.7, 77.0 and 72.0 larvae per vine respectively) and the yields recorded from these genotypes were significantly lower than the local types. © 2017 Association for Advancement of Entomology

KEY WORDS: Snake Gourd, Semilooper, *Anadevidia peponis*, genotypes

Snake gourd *(Trichosanthes anguina* L.*)* is a common Cucurbitaceous vegetable and it is an important summer vegetable, cultivated throughout the year except in extreme winter. It is a popular vegetable with high nutritive value. It is as important as a good source of minerals, fibers and other nutrients to make the food wholesome and healthy (Rahman *et al*., 2002). The plant is regarded as a blood purifier and used in curing skin diseases. The snake gourd is regularly attacked by the semilooper, (*Anadevidia peponis*). (Lepitoptera: Noctuidae). Several chemicals are tried to combat this pest. However, in the changing scenario of pest management programme, host plant resistance plays an important role (Sandhya *et al*., 2010). In view of above, an attempt was made to evaluate certain newly identified snake gourd genotypes against semilooper under field condition.

The present investigation was conducted in the Department of Horticulture, Agricultural College and Research Institute, Madurai during the period 2011-12 (*Rabi* and *Kharif* 2012). Fifty genotypes were collected from different geographical locations and utilized for the study. Among them, 40 genotypes from NBPGR, New Delhi, three from Tamil Nadu Agricultural University, Coimbatore and seven local types respectively from Kulithalai, Kumbakonam, Palayajeyamkondam, Nagappattinam, Jeyamkondam, Madurai and Coimbatore were collected for evaluation. The experiment was laid out in a Randomized Block Design with three replications. The seeds were sown at a spacing of 2m x 2m with recommended package of practices for the state of Tamil Nadu without plant protection measures. The data on semilooper incidence were recorded from first appearance to peak infestation during February 2012. Observations were recorded at weekly intervals between 7.00 to 10.00 AM. The semilooper comprising of all instars were counted from each plant in each replication. The data were

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Table 1. Incidence of the Semilooper, *Anadevidia peponis* on snake gourd genotypes (average of Rabi 2011 and Kharif 2012)

Genotypes	No. of insect/ vine	Yieldtonnes / hactare
IC202158	59.00	29.25
IC 413027	65.00	33.15
IC212416	58.00	28.63
IC333314	55.00	42.84
IC347377	61.00	14.75
IC410159	60.00	15.67
IC410160	72.00	30.37
IC284753	63.30	18.45
IC202159	58.70	30.00
IC411877	84.70	20.18
IC413589	63.70	17.57
IC418478	91.00	18.90
IC470904	56.33	22.23
IC212474	60.33	26.12
IC539825	65.00	20.90
IC212465	59.70	34.83
IC202155	55.00	28.83
IC433526	64.00	29.16
IC212475	54.00	26.12
IC411878	77.00	20.18
IC308557	55.00	24.00
IC212509	58.30	28.00
IC410142	61.00	21.37
IC212512	64.00	25.20
IC202157	53.00	32.92
IC212527	56.30	28.64
IC410146	60.00	21.75
IC284875	65.00	19.00
IC426984	59.00	16.12
IC321016	56.00	23.77
IC277390	63.00	20.23
IC546083	65.00	31.64
IC321019	59.00	26.82
IC212513	61.00	23.85
IC265568	69.00	22.19
IC265646	53.00	29.92
IC427743	58.00	26.12
Nagapattinum local	59.00	11.62
Kumbakonam local long	49.00	32.81
Kumbakonum local short	47.00	23.75
Jeyamkondam local short	51.00	26.25
Kulithalai local	43.00	36.64
Coimbatore local	59.00	42.00
Co2	55.00	22.55
MDU-1	54.00	33.75
PKM-1	49.70	23.52
Madurai local long	49.00	33.62
Madurai local short	63.00	32.55
Palayajeyamkondam local	51.00	41.10
SE.d	2.82	2.99
CD	5.59	6.02

suitably analyzed and used for interpretation of results (Gomez and Gomez, 1984).

The results on incidence of semilooper, *Anadevidia peponis* in field revealed that the 50 germplasms evaluated had different levels of infestation at peak vegetative growth stage of snake gourd (Patil and Bhole, 1993). The semilooper infestation in snake gourd envisaged that significant lowest semilooper infestations were found in the Kulithalai local and Kumbakonam local short types ranging from 43 to 47 larvae per vine. This was followed by Kumbakonam local long, Madurai local long and PKM-1 ranging from 49 to 49.70 larvae per vine. However, all the germplasms were found to be on par for the infestation to semilooper. The germplasms IC418478, IC411877, IC411878 and IC410160 were found to be highly susceptible to semilooper which registered a significantly higher population of semiloopers compared to rest of the genotypes (Table 1). The highest yield observed in IC333314 (42.84 t/ha), Palayajeyamkondam local (41.10 t/ha), Kulithalai local (36.64 t/ha) IC212465 (34.83 t/ha) and IC202151 (32.92 t/ha) may be due to the genetic potential of the germplasm even though they recorded considerable population of semilooper. The results indicated that the snake gourd local varieties *viz*., Kulithalai local short, Kumbakonam local short, Kumbakonam local long, Madurai local long and PKM-1 recorded low infestation by semilooper besides registering higher yield and may be utilized for further improvement in breeding programme.

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Short Communication No. ent 42113

Natural control of mealybug, *Nipaecoccus viridis* (Newstead) by coccinellid predator, *Nephus regularis* (Sicard) on Jujube (*Ber*)

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ABSTRACT: Regular surveys carried out in the *ber* growing regions of Punjab revealed a predatory coccinellid beetle, *Nephus regularis* (Sicard) on spherical mealybug, *Nipaecoccus viridis* (Newstead) infesting *ber* trees. On an average, 60 and 80 per cent mealybug infestation was recorded at Ludhiana and Amritsar, respectively whereas, 8 and 12 per cent predation of *N. regularis* was recorded in the respective districts. While rearing mealybug in laboratory, approximately 3-4 beetles were observed to emerge from pre-adult stages present in waxy covering of mealybug colony per 10-15 cm long mealybug infested twig with leaves collected from both the locations.

KEYWORDS: Mealybug, *Nipaecoccus viridis*, predator, *Nephus regularis*, Jujube (*Ber*)

Jujube, *Zizyphus mauritiana* Lamarck, commonly known as *ber* is one of the archaic and common fruits of Punjab. It is an important part of religious and cultural history of Punjab. Commercial cultivation of *ber* is being done in the districts Sangrur, Patiala, Mansa, Bathinda, Fazilka and Ferozepur. *Ber* is rich in vitamin C, protein and minerals *viz.* calcium, phosphorus and iron. It is cultivated on 1802 ha area in Punjab and producing 29967 MT fruits with productivity of 16630 kg/ha and ranks sixth in area after Kinnow mandarin, mango, guava pear and litchi (Anonymous, 2015). *Ber* fruits are utilized for preparing *murabba*, pickle and *chutney*; juicy varieties are used to make beverages and fully mature fruits are often canned in sugar syrup.

So far, 37 insect and mite pests have been reported from Punjab infesting different parts of *ber* trees (Singh, 2016; Singh *et al*., 2016). Among these, spherical mealybug, *Nipaecoccus viridis* (Newstead) (Fig. 1) is an important insect pest of *ber* in Punjab. It is a polyphagous insect and is geographically distributed in Asia, Africa, North

Fig. 1 Mealybug, *Nipaecoccus viridis* (Newstead) on infested *ber* leaves and twigs

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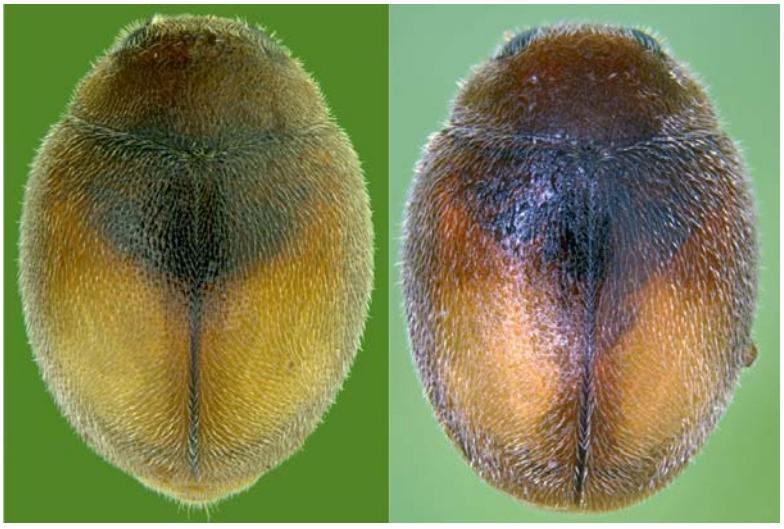

Fig. 2 Beetle, *Nephus regularis* (Sicard)

America, Central America & Caribbean and Oceania. In India, it is present in Andhra Pradesh, Bihar, Delhi, Goa, Gujarat, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu, Uttar Pradesh and West Bengal (Anonymous, 2005). *Nipaecoccus viridis* is reported as an important pest of horticultural crops in Punjab (Sharma and Arora, 2009). This mealybug is also reported to attack grapes, citrus and guava in Punjab (Sharma, 2011). The pest attacks over 100 plant species in more than 30 families in different ber growing countries. Major crops include soybean, citrus, mango, tamarind, pomegranate and grapevines. It is a common pest of ornamentals such as Mimosaceae and Moraceae, *Hibiscus* spp. and *Ziziphus* spp. (Mendel and Bloomberg, 2015). *Alamella flava* (Agarwal, 1966) and *Anagyrus* sp. & *A. gunturiensis* [*A. mirzai* Agarwal] have been reared from *N. viridis* collected on coffee at Karnataka, India (Chacko and Singh, 1980). *Euryischomyia alami* Girault [*E. washingtoni*] has also been reported from Karnataka, India (Shafee, 1975). *Nephus ryuguus* have been reported as a natural enemy of *N. viridis* from Taiwan (Anonymous, 2008). Twenty eight biocontrol agents predating/parasitizing insect pests of Indian jujube from Punjab have been reported by Singh *et al*., 2016 from the orders Coleoptera (7), Hymenoptera (5), Dictyoptera (3), Diptera (3), Odonata (2) and Aranae (8).

Survey and surveillance of jujube orchards were carried out to study the natural enemy complex on insect pests of jujube in the Punjab. Roving surveys were conducted in the three agro climatic zones i.e., South Western arid zone, central plain zone and sub montaneous zone along with fixed plot surveys in the Fruit Research Farm and College Orchard of the Punjab Agricultural University, Ludhiana. Different life stages of insect pests and natural enemies were collected and reared in the Fruit Entomology Laboratory, Department of Fruit Science of the University.

During these surveys, heavy mealybug infestation (Fig. 1) was recorded at district Ludhiana (60 %) and Amritsar (80 %). Observations on predation by *Nephus regularis* (Sicard) (Coleoptera: Coccinellidae: Scymninae: Scymnini) (Fig. 2), revealed 8 and 12 % predation in the field conditions at Ludhiana and Amritsar, respectively. During laboratory rearing of mealybug *N. viridis* infested *ber* twigs (collected from *ber* orchards of village Gurhe, District Ludhiana and from historical *ber* trees at Darbar Sahib, Amritsar), predatory beetles

N. regularis were recovered. From the pre-adult stages (eggs, larvae and pupae) in the waxy covering of mealybug colonies on collected infested samples emerged *N. regularis* beetles under laboratory conditions. On an average, 3 - 4 *N. regularis* beetles emerged per 10-15 cm long *N. viridis* infested twigs having leaves at room temperature during April-May of 2015 and 2016 from both the locations.

This predatory beetle is reported to be distributed in the states of Andhra Pradesh, Assam, Karnataka and Madhya Pradesh of India (Poorani, 2002: NBAIR, 2013). *Nephus regularis* is a foe of *N. viridis* from New Zealand (Rhode and Crosby, 2013). This short oval coccinellid predatory beetle was observed to be having an approximate body length of 1.5-1.7 mm and width 1.2-1.4 mm. Elytra were light brown with dark brown to blackish patch towards thorax. Head and pronotum were observed to be brown in colour. Antennae of this predatory beetle were 10-segmented. Maxillae having terminal segment cylindrical/parallel-sided and apical margins obliquely truncated. Prosternal processes are reported to be broader than long, without carinae and finely punctate. Postcoxal line is recorded to be incomplete, parallel to posterior margin of first abdominal ventrite for up to 4/5th of its length and then very slightly recurved, area enclosed by postcoxal line with evenly distributed punctures, slightly smaller near line. Median lobe of tegmen of male genitalia is slightly asymmetrical (NBAIR, 2013).

N. regularis has an abundance of 4.6 to 5.6 per cent on solenopsis mealybug, *Phenacoccus solenopsis* Tinsley on cotton (Neetan and Aggarwal, 2011: Kedar *et al*., 2011). Highest population densities were recorded in last week of July for *N. regularis* associated with *P. solenopsis* on cotton (Kedar *et al.,* 2011a). *Nephus regularis* have also been reported from Solanum mealybug, *Phenacoccus solani* Ferris (Gautam *et al.,* 2007).

If multiplied and released in large number, this predatory beetle, *N. regularis* can effectively manage the mealybug *N. viridis* population on *ber* trees.

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