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Cover image: *Telenomus oryzae* Rajmohana & Nisha, 2013

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ISSN 0973-1555 © SHBBIR R KHAN AND NEELKAMAL RASTOGI

Recolonisation patterns of orthopteran species in successional stages of revegetated coal mine sites

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Abstract

The diversity and abundance of insects belonging to the order Orthoptera was studied in coal mine spoils of different ages (0- 10 year old) located in Singrauli and the adjoining border area between Uttar Pradesh and Madhya Pradesh in India. The abundance of the 21 orthopteran species (belonging to 16 genera) showed significant variations in 0-8 year old mine sites relative to the 10 year old reference site. Orthopteran alpha diversity increased sharply in the 2 year old site. The gradual increase in alpha diversity in the 4-10 year old sites did not demonstrate any significant differences. However, abundance and number of grasshopper species showed a clear linear increase with increase with mine site rehabilitation. Overlap in orthopteran rank abundance curves obtained for 4-10 year old sites is probably due to differences in the occurrence, abundance and diversity patterns of grasshopper and cricket species with increase in mine site rehabilitation age. Our results demonstrate that grasshopper species assemblages are highly sensitive to variations in the level of anthropogenically-caused disturbance, due to mining activities. Thus, the abundance patterns of grasshoppers, including those of habitat specialists, may be of significance in evaluation of the restoration progress in degraded ecosystems, such as mine sites.

Keywords: *Grasshoppers, insect diversity, degraded ecosystems, recolonisation patterns.*

Introduction

Anthropogenically-caused environmental degradation and the consequent adverse impact on biodiversity are of worldwide concern (Bengtsson *et al.*, 2000; Folke *et al.*, 2004; Dornelas, 2010). The restoration of degraded lands such as mine sites is a priority area in conservation biology (see recent review by Suding, 2011), since mine spoils (the piles of accumulated over-burden excavated during the mining process) cause ecosystem degradation by destruction of flora and fauna. Though succession and recolonisation by vegetation and vertebrate wildlife on reclaimed mine lands has been studied (Majer, 1989), diversity patterns of early colonising invertebrate species needs greater attention since they play a vital role in the re-establishment of a functioning ecosystem (Majer, 2009).

Arthropods are found to occupy a wide diversity of microhabitats and niches. Moreover, they play more diverse ecological roles than any other group of animals. Their short generation times and their small size makes arthropods, particularly insects, ideal organisms for monitoring spatial and temporal changes in habitat quality and restoration success (Longcore, 2003). Hence, among the mine site fauna, insects need to be targeted for assessment of the recolonising patterns.

In revegetated mines, the colonising patterns of insect herbivores assume special significance, since these may influence

ecosystem succession via herbivory and may also reflect the rehabilitation process. Insects belonging to the order Orthoptera play a critical role in grassland ecosystems, since they constitute the major proportion of arthropod biomass (Shure and Phillips, 1991). Grasshopper assemblages appear to play the main roles in forming and maintaining the biodiversity and the stability of various kinds of grassland ecosystems (Guo *et al.*, 2006). Moreover, orthopteran nymphs are highly mobile (Floren *et al.*, 2001), allowing orthopteran communities to closely follow plant communities with progressive adjustments during the season (Joern, 1982; Parmenter *et al.*, 1991; Bonnet *et al.*, 1997). Grasshopper biodiversity is not only considered to be a product of the evolution of grassland ecosystems; a close relationship is also found between grasshopper biodiversity and the health of grassland ecosystems (Guo *et al.*, 2006).

Hence, the present study focuses on orthopteran diversity and abundance in coal mine spoils of different ages to elucidate the recolonisation patterns of grasshoppers and crickets following anthropogenic disturbances caused by surface mining activities. Information related to insect recolonisation and successional patterns should be useful to land managers in the development of suitable strategies for reconstruction of disturbed ecosystems.

Materials and Methods

Study Site

Investigation of the diversity and abundance of insects belonging to the order Orthoptera was conducted at six coal mine dump sites of various ages (0, 2, 4, 6, 8 and 10 years) established from 2001 to 2011. The original vegetation is that of a tropical dry deciduous forest (Singh, 2012). Forty - six plant species were planted by the mining company at each dump site about 1.5 years after establishment of the mine dumps. The coal mine sites of Northern Coalfields Ltd., are situated at Singrauli and the adjoining border area lying between Uttar Pradesh and Madhya Pradesh in India (latitudes 23° 47' to 24° 12' N and longitudes 81° 48' to 82° 52' E). The vegetation in the mine sites is dominated by *Eragrostis unioloides*, *Saccharum spontaneum*, *Bambusa bamboo*, *Euphorbia hirta*, *Acacia catechu*, *Acacia nilotica*, *Acacia mangium*, *Dalbergia sissoo* and *Prosopis juliflora*, plants (Singh, 2011, 2012).

Sampling Methods

The orthopteran populations were sampled from February to March, 2012 and again during October – December, 2012. Two main methods were used to record the diversity and abundance of orthopterans at the six mine sites. These included: (1) the visual scanning, and (2) the sweep netting, methods. In the visual scan method, a metal quadrat frame was used and, the number and diversity of orthopterans were recorded in the quadrats (area = 1 m^2, n = 125 per day per site) which were randomly placed on the ground surface, over a period of five days (n = 625 per site). The sweep netting method involved random sweeping (n = 20 per site) of the ground, bushes and shrubs to capture the orthopterans, by using an insect net. Samples were preserved in 75% alcohol and taken to the laboratory for sorting and identification to genus/species level. Identification of the orthopteran specimens was done with the help of experts from the Department of Zoology, Aligarh Muslim University.

Data Analysis

Species diversity (alpha and beta diversity) at each mine site was calculated according to the Shannon–Weiner and Whittaker index methods, respectively.

Changes in the overall orthopteran abundance with mine site rehabilitation was analysed by carrying out one-way analysis of variance (ANOVA) followed by Dunnett's and

Duncan's Multiple Range post hoc Tests (DMRT) ($p < 0.05$), tests for analysis of abundance and of alpha diversity, respectively. Variance followed by DMRT post-hoc test was also applied to analyse in the abundance of grasshoppers and crickets in the 0 - 10 year old sites. Since no pristine areas were available, the dump site established in 2001 (10 years old) was taken as the reference site for determination of beta diversity and for the Dunnett's post-hoc test.

The orthopteran diversity at different sites was compared using the rank abundance plot in which percentage cumulative abundance (log) was plotted against species rank.

All orthopteran species restricted to specific succession stages were classified as habitat specialists. All others consistently recorded in 2-10 year old sites were referred to as habitat generalists (Table. 1).

All statistical analyses were done by using SPSS (16.0) statistical package (SPSS Inc, Chicago, USA; 1997) and MS Excel 2007.

Results

Species diversity and abundance

A total of 21 orthopteran species belonging to 16 genera were recorded in this study. The five orthopteran families present comprised Acrididae (10 species and 8 genera), Pyrgomorphidae (7 species and 4 genera), Gryllidae (2 species, 2 genera), Eumastacidae and Tettigoniidae (1 species and 1 genus, in each case) (Table 1).

Abundance of the 21 orthopteran species showed significant variations at all the five mine sites (0-8 year old), relative to the reference site: *Acrida conica, Acrida exaltata, Gastrimargus africanus, Leva cruciata, Pyrgomorpha* sp., *Chrotogonus* sp., *Lepidogryllus* sp., *Chrotogonus armatus, Spathosternum prasiniferum, Gastrimargus musicus, Oxya fuscovittata, Atractomorpha psittacina Carnarvonella* sp., *Pterophylla* sp., *Metioche* sp., *Catantops pinguis, Atractomorpha crenulata, Chrotogonus trachypterus, Sphingonotus savignyi, Bryodema luctuosa, Oedaleus abruptus* (One-way ANOVA: F = 52.823; 21.798; 33.607; 24.252; 18.672; 16.725; 5.253; 12.851; 42.073; 14.896; 30.889; 37.003; 7.626; 11.808; 8.584; 9.339; 16.933; 13.384; 16.170; 18.617; 17.806, respectively, df = 5, 3749 ; $p < 0.001$ in each case) (Fig. 1 a-c).

Dunnett's Post hoc test revealed significantly lower abundance of *A. exaltata, G. africanus, L. cruciata, S. prasiniferum,* and *Pterophylla* sp. in the 0-6 year old sites ($p < 0.001$, in each case) relative to the reference site. The abundance of *A. conica, Pyrgomorpha* sp., *Chrotogonus* sp., *G. musicus, A. crenulata, C. trachypterus* and *S. savignyi* in the early-intermediate successional stages, (0 - 4 year old) was significantly lower ($p < 0.001$, in each case) relative to their abundance in the 10 year old site. In the newly established dump sites (0 - 2 year old), abundance of *C. armatus* and *C. pinguis* was significantly lower ($p < 0.001$, in each case) in comparison to that found in the reference site. However, *B. luctuosa, O. abruptus, Carnarvonella* sp, and *Metioche* sp. found in the 4 and 6 year old sites were completely absent in the reference site. The abundance of *O. fuscovittata* and *A. psittacina,* was significantly lower ($p < 0.001$, in each case) in all the five (0-8 year old) mine sites relative to the climax site. Both *A. exaltata* and *L. cruciata* exhibited lower abundance (respective significance values being $p < 0.01$ and $p < 0.05$) in the 8 year old site. Although the abundance of *Pyrgomorpha* sp. *Chrotogonus* sp., *A. crenulata, S. savignyi* and *G. musicus* was progressively higher on moving from 2 - to 8-year old sites, significantly lower values relative to the reference site were obtained only in the

Table-1: Orthopteran diversity, feeding guilds, habitat specificity and stages recorded in the 0-10 year old mine sites by using the visual scanning and sweep netting methods (H = Herbivores and D = Detritivores).

Family	Species	Habitat specificity	Feeding guild	Sampling methods			
				Visual Scanning		Sweep Netting	
				Nymphs	Adults	Nymphs	Adults
Acrididae	*Acrida conica*	Generalist	H	+	+	+	+
Acrididae	*Acrida exaltata*	Specialist	H	-	+	+	+
Acrididae	*Gastrimargus africanus*	Generalist	H	-	+	+	+
Acrididae	Spathosternum prasiniferum	Specialist	H	+	+	-	-
Acrididae	Gastrimargus musicus	Generalist	H	+	+	-	+
Acrididae	Oxya fuscovittata	Specialist	H	+	+	-	+
Acrididae	*Catantops pinguis*	Generalist	H	-	+	-	-
Acrididae	*Sphingonotus savignyi*	Generalist	H	+	+	-	+
Acrididae	*Bryodema luctuosa*	Specialist	H	+	-	-	-
Acrididae	*Oedaleus abruptus*	Specialist	H	+	+	-	+
Pyrgomorphidae	*Leva cruciata*	Generalist	H	+	-	+	+
Pyrgomorphidae	*Pyrgomorpha* sp.	Generalist	H	+	-	+	+
Pyrgomorphidae	Chrotogonus sp.	Generalist	H	+	+	+	+
Pyrgomorphidae	Chrotogonus armatus	Generalist	H	+	-	+	-
Pyrgomorphidae	*Atractomorpha psittacina*	Specialist	H	-	+	-	+
Pyrgomorphidae	*Atractomorpha crenulata*	Generalist	H	-	+	-	+
Pyrgomorphidae	*Chrotogonus trachypterus*	Generalist	H	-	+	+	+
Gryllidae	*Lepidogryllus* sp.	Generalist	D	+	+	+	+
Gryllidae	*Metioche* sp.	Specialist	D	+	+	+	+
Tettigoniidae	*Pterophylla* sp.	Specialist	H	+	-	+	-
Eumastacidae	*Carnarvonella* sp.	Specialist	H	+	-	+	-

case of the 2 - 4 year old sites. The abundance of *C. pinguis* was significantly lower in the 0-2 ($p < 0.001$) and 4 ($p < 0.01$) year old sites relative to the reference site. *Acrida conica, G. africanus, Pyrgomorpha* sp., *Chrotogonus* sp., *S. prasiniferum, G. musicus, Carnarvonella* sp., *Pterophylla* sp., *A. crenulata, S. savignyi* and *B. luctuosa,* did not demonstrate any significant differences in their abundance at the 8 year old dump site in comparison to the climax site. Significant differences were also not obtained in the abundance of *Lepidogryllus* sp., *C. armatus, C. pinguis* and *C. trachypterus* at the 6 and 8 year old sites. *Metioche* sp. and *O. abruptus* abundance did not vary significantly at the 0, 2 and 8 year old dump sites in comparison to the climax, 10 year old site. *Carnarvonella* sp. was recorded only in 4 and 6 year old sites. Since all the species were absent in the 0 year old dump site, the abundance of each revealed highly significant values ($p < 0.001$, in each case) with respect to that for the reference site.

While twelve orthopteran species were found to be generalist species progressively increasing in abundance in the 2-10 year old sites, an exception was *Lepidogryllus* sp. which did not show any specific pattern with increase in restoration.

There were nine habitat specialist orthopteran species. *Carnarvonella* sp., *Metioche* sp., *Bryodema luctuosa* and *Oedaleus abruptus* were found only in 4 - 6 year old sites which had intermediate level of disturbance. In contrast, *Acrida exaltata, Spathosternum prasiniferum, Oxya fuscovittata, Atractomorpha psittacina* and *Pterophylla* sp. were restricted to the maximally restored, 8 and 10 year old sites.

Alpha diversity increased with the age of the coal mine sites from 0 to 10 years (Fig. 2). One-way ANOVA indicates significant differences in the orthopteran alpha diversity at the five (2-10 year old) study sites ($F_{5, 24} = 344.465$, $p < 0.001$). The 4-10 year old mine sites showed a very gradual increase in alpha diversity. However, the DMRT post hoc test revealed highly significant differences between alpha diversity found in the 0 and 2 year old site in comparison to the 6 and 8 year old and the reference, sites. Significant differences in diversity were also obtained between the 0, 2 and 4 year old sites. No significant differences were obtained between 6, 8 and 10 year old sites.

Beta diversity was highest in the 4 and 6 year old sites and lowest in the 2 year old dump site, while there was no difference in the species composition of the 8 and 10 year old dump sites (Fig. 3). While grasshopper abundance and number of species showed a linear increase, (the curve was steep initially and more gradual in the late successional stages) in the case of crickets, both parameters demonstrated a decrease in the later, 8-10 year old mine sites (Fig. 4). One-way ANOVA of grasshopper abundance showed highly significant differences ($F_{5, 24} = 1198.843$, $p < 0.001$) in the 0-10 year old sites, although abundance of crickets demonstrated a lower significance value ($F_{5, 24} = 3.186$, $p < 0.05$). The DMRT post hoc test revealed significant differences in grasshopper abundance among the 0-10 year old sites, while the abundance of crickets showed significant differences between 0 and 2-6 year old sites. No significant differences were found between 2-10 year old sites (Fig. 4)

Rank abundance patterns revealed that lowest orthopteran diversity is found in the 2 year old site (the uppermost curve). There was overlap between the rank abundance curves obtained for the 4-10 year old sites (Fig. 5).

Discussion

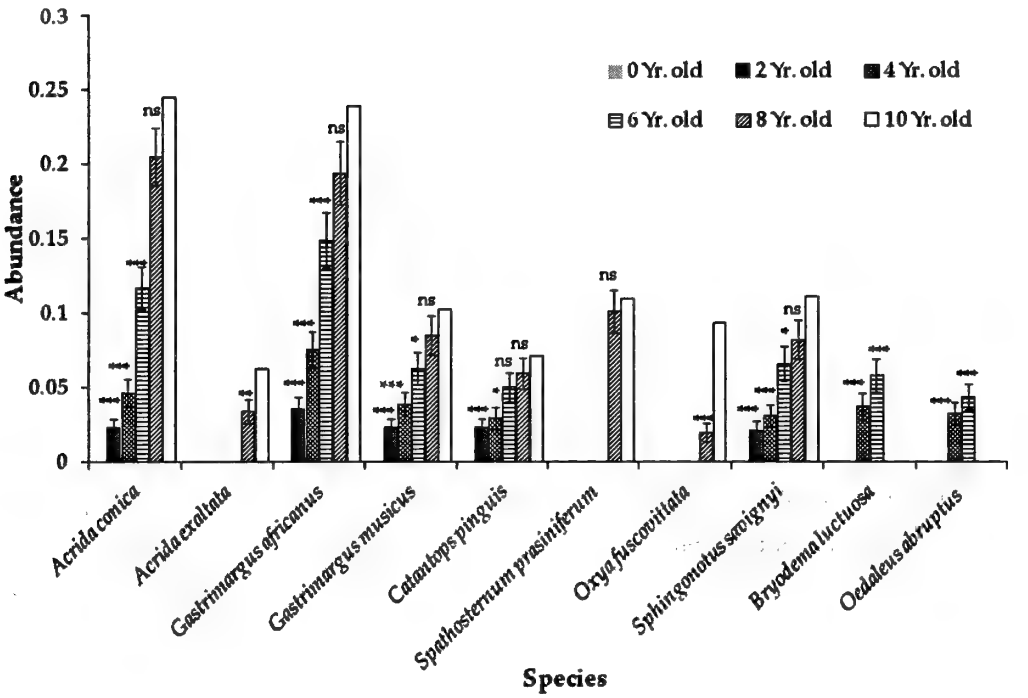
Our results reveal that grasshoppers are early colonisers of revegetated mine sites, since out of the 12 orthopteran species recorded at the 2 year old site, 11 species were of grasshoppers and only a solitary species of cricket (*Lepidogryllus* sp.) was found. Acrididae and

Pyrgomorphidae were species rich families dominant at the mine sites. While *G. africanus* remained consistently abundant in the 2-10 year old spoils, *A. conica* abundance increased gradually, reaching peak values only in the 10 year old, climax, successional stage (Fig. 1). Three species of grasshoppers, *Carnarvonella* sp., *B. luctuosa* and *O. abruptus* preferred habitat conditions prevalent in 4 and 6 year old dump sites and were totally absent in the late successional stages. Some grasshopper species appear to be highly sensitive to environmental disturbances caused due to mining activities. Thus, *A. exaltata, O. fuscovittata* and *Pterophylla* sp. appear to be late- colonising grasshopper species, arriving much later i.e. in the almost restored, 8 year old mine site, onwards. Our results thus support earlier studies, carried out in rangelands, which show that grasshopper species assemblages are highly sensitive to the level of disturbance (Kemp *et al.*, 1990).

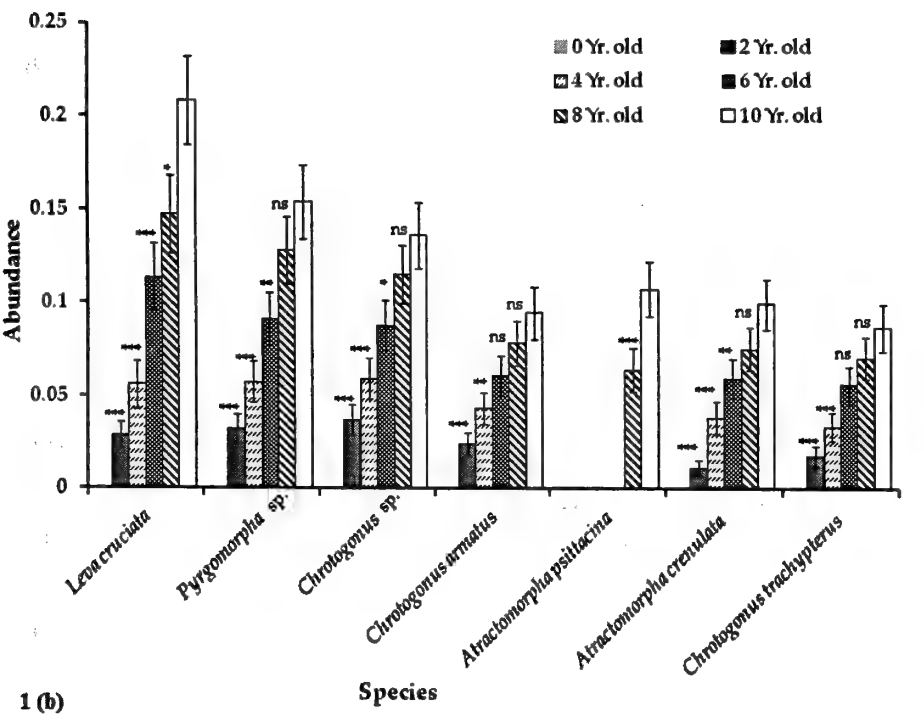
Orthopterans were totally absent in the newly established mine sites. However, alpha diversity of orthopterans progressively but gradually increased (although not significantly) in the 4-10 year old sites. Beta diversity exhibited a gradual increase, reaching highest values in the 4-6 year old sites, there being no difference in orthopteran diversity between the 8 and 10 year old sites. Alpha diversity and rank abundance patterns indicate that orthopteran diversity is low in the highly disturbed site (2 year old) but after increasing sharply in 4 year old site, at intermediate levels of disturbance does not increase significantly in the more disturbed, 6-10 year old sites. The lack of a clear pattern in rank abundance curves obtained for 4-10 year old sites may be due to the fact that while the alpha diversity of orthopterans does not differ significantly between sites with intermediate and low levels of disturbance, abundance levels are significantly higher in the less disturbed sites. Secondly, the number of species of crickets (i.e. decomposers) decreased while those of herbivorous grasshoppers increased with increase in mine site rehabilitation age. Moreover, while some species are habitat specialists, characteristic of specific successional stages (either with low or high disturbance levels), others are generalists which gradually increase in abundance along the descending disturbance gradient.

The abundance and diversity of crickets (decomposer feeding guild, Gullan and Cranston, 2000) showed a steep increase initially but decreased in the 8-10 year old mine sites. While *Metioche* sp. showed an increasing abundance trend in the 4 to 6 year old mine sites and was absent in later stages, *Lepidogryllus* sp. did not demonstrate any abundance pattern in the 2-10 year old sites. Thus, decomposers are found to be more abundant in the early successional stages and gradually decrease and give way to the herbivores in the late successional 8 year old site and the climax, 10 year old mine site. Earlier studies on newly abandoned arable land, meadows with large mammal grazing pressure and protected semi-natural steppe meadow, report orthopteran assemblages to be more stable on the undisturbed and intermediate disturbance level sites (Baldi and Kisbenedek, 1997). In the complete absence of significant grazing by mammalian herbivores at the mine sites, the herbivorous grasshoppers and decomposer crickets provide an important ecological pathway for energy flow and nutrient cycling.

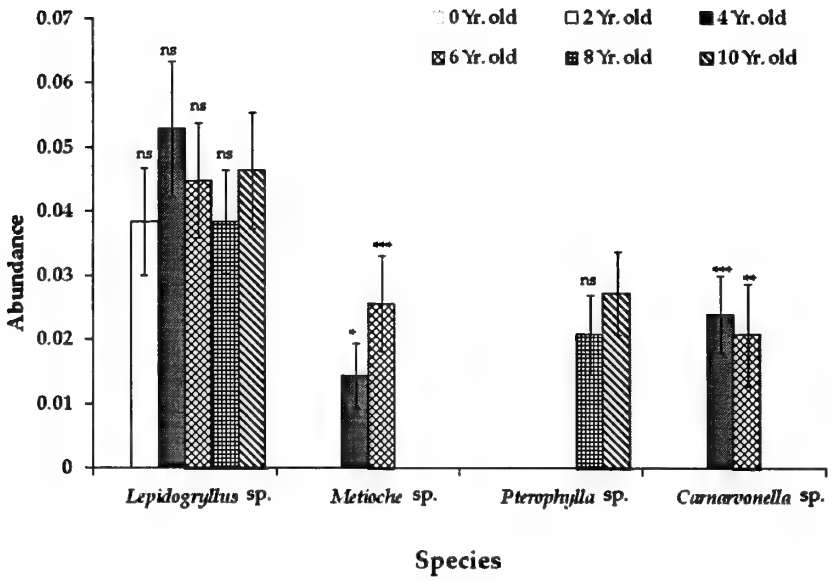
Being a major source of food for predatory arthropods (Schmitz, 2008), orthopteran species may influence other organisms during the re-colonisation process. They are also important components of the food chain for many insectivorous birds and mammals (Capinera *et al.*, 1997; Mayya *et al.*, 2005), Alteration of orthopteran population dynamics is expected to affect several trophic levels in the food chain (Capinera *et al.*, 1997).


0 Yr. old
2 Yr. old
4 Yr. old
6 Yr. old
8 Yr. old
10 Yr. old
Abundance
0.3
0.25
0.2
0.15
0.1
0.05
0
Acrida conica
Acrida exaltata
Gastrimargus africanus
Gastrimargus musicus
Catantops pinguis
Spathosternum prasiniferum
Oxya fuscovittata
Sphingonotus savigmyi
Bryodema luctuosa
Oedaleus abruptus
Species

1 (a)


0 Yr. old
2 Yr. old
4 Yr. old
6 Yr. old
8 Yr. old
10 Yr. old
Abundance
0.25
0.2
0.15
0.1
0.05
0
Leva cruciata
Pyrgomorpha sp.
Chrotogonus sp.
Chrotogonus armatus
Atractomorpha psittacina
Atractomorpha crenulata
Chrotogonus trachypterus
Species

1 (b)



1 (c)

Fig.1: Abundance of orthopteran species belonging to different families: (a) Acrididae, (b) Pyrgomorphidae, (c) Gryllidae, Tettigoniidae and Eumastacidae, in coal mine spoils established in 2011 (0 year old), 2009 (2 year old), 2007 (4 year old), 2005, (6 year old), 2003 (8 year old) and 2001 (10 year old, reference site). One-way ANOVA followed by Dunnett's post hoc test: * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$, ns- Not significant.

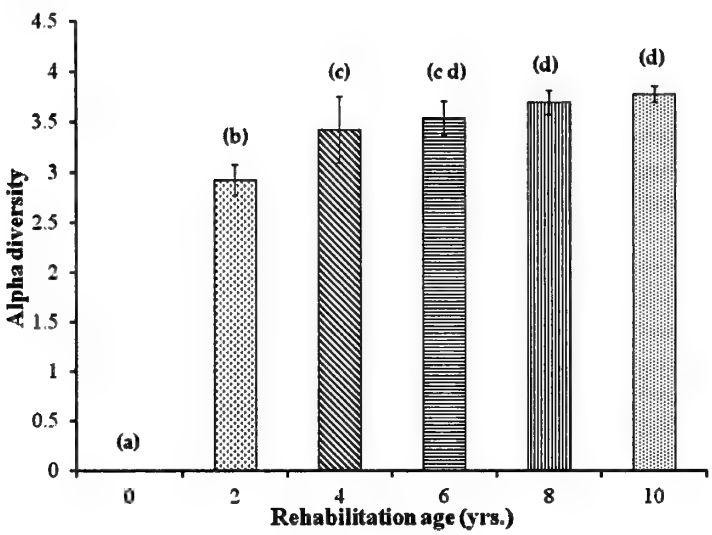


Fig.2: Alpha diversity of orthopteran species in 0 to 10 year old coal mine sites (established in 2011, 2009, 2007, 2005, 2003 and 2001, respectively). One way ANOVA followed by Duncan's Multiple Range Test (DMRT) ($p < 0.05$) were used to compare the calculated orthopteran alpha diversity at different coal mine sites. Different letters denote significant differences ($p < 0.05$) among orthopteran alpha diversity at different sites (0-10 year old).

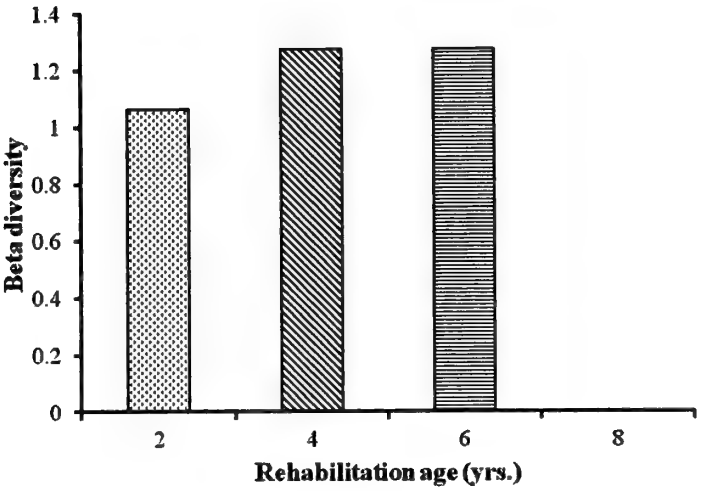


Fig.3: Beta diversity of orthopteran species in 2-8 year old coal mine sites (established in 2009, 2007, 2005 and 2003, respectively).

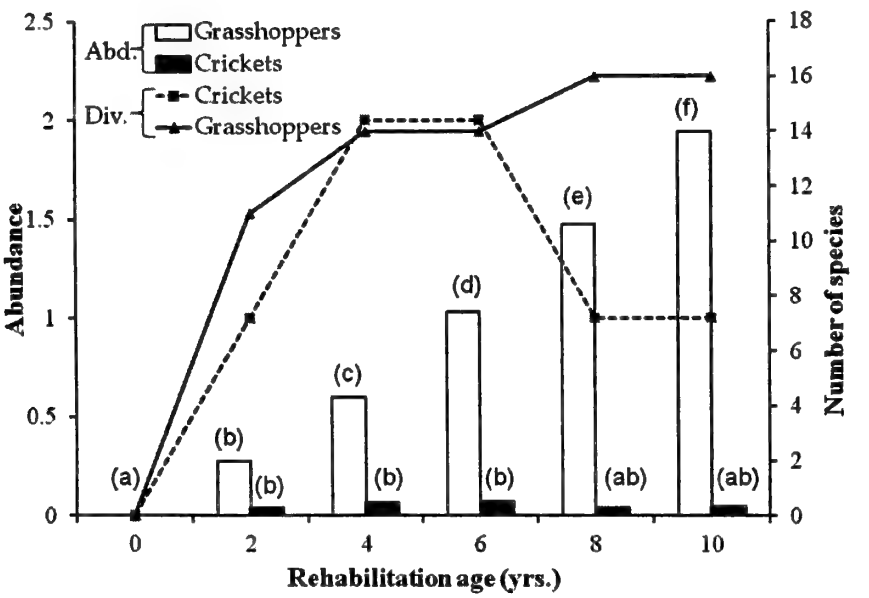


Fig.4: The diversity and abundance of grasshoppers and cricket species in 0-10 year old coal mine sites (established in 2011, 2009, 2007, 2005, 2003 and 2001, respectively).

□ = Abundance of grasshoppers, ■ = Abundance of crickets,

—▲— = Diversity of grasshoppers, —■— = Diversity of crickets

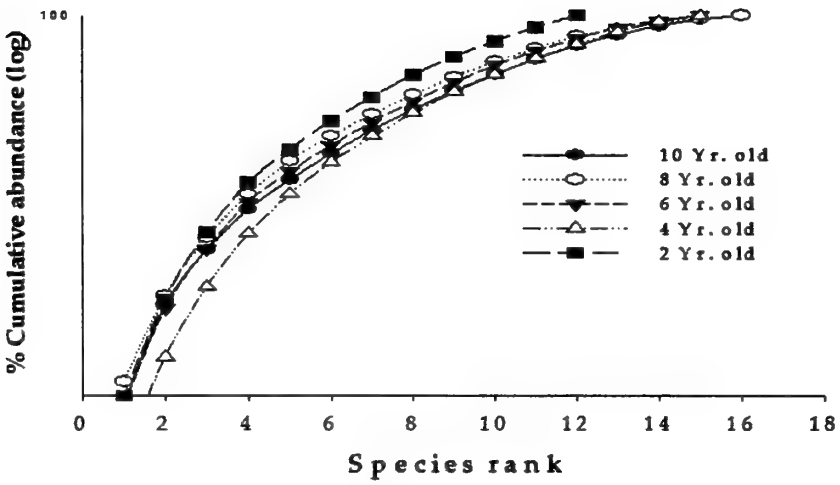


Fig.5: Species rank abundance plot of orthopteran community in 2 to 10 year old coal mine sites (established in 2009, 2007, 2005, 2003 and 2001, respectively).

The results of the present study clearly demonstrate a strong relationship between anthropogenic disturbances due to mining activities and orthopteran assemblage compositions in mine sites of different ages. Grasshopper diversity and abundance varied linearly with degraded ecosystem rehabilitation, suggesting the important role of grasshoppers in food webs operating in the mine sites. Since grasshopper assemblages are documented to show stronger differentiation among disturbed sites not evident even on the basis of floristic data (Andersen *et al.,* 2001), the abundance patterns of grasshoppers, particularly those of habitat specialists, may be of significance in the evaluation of restoration progress in degraded ecosystems.

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ISSN 0973-1555 © RAJINDER KAUR AND NEELIMA R KUMAR

Pollen foraging activity of *Apis mellifera* during autumn season in Chandigarh

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Abstract

Foraging activity of honeybee *Apis mellifera* was studied during autumn season in Chandigarh. The collection of pollen by worker bees was influenced by number of factors including both internal and external. Internal factors like higher area under brood in the colony stimulated the foragers to collect more pollen. External factors such as temperature, light, wind, rain, clouds also influenced the pollen foraging activities. Number of pollen foragers returning with pollen loads at the hive entrance was counted for 5 minutes (September-November, 2011) at intervals of 1 hour each from 10:00 a.m. to 04:00 p.m., twice a week in five honeybee colonies during autumn season. The mean maximum number of pollen foragers was recorded as 218.38 ± 33.27 at 12:00 noon when air temperature ranged from 15°C to 32°C. This pollen collecting activity decreased after 03:00 p.m. Number of trips depended upon various conditions including weather, forage availability, strength of colony etc. The results of findings revealed that 12:00 noon was the hour of peak pollen collecting activity during autumn season and *Cassia siamea* present in large number near the colonies was the main source of collected pollen.

Keywords: *Honeybees, foraging, pollen, autumn.*

Introduction

Honeybee is one of the most familiar insects in the world. This member of the insect order Hymenoptera plays a key role in human and environmental health. Honeybees are social insects. Each bee belongs to one of the three specialized groups called castes viz., queen, drones and workers.

The development of honeybees largely depends upon the food they are fed. So, the nectar and pollen collection by honeybees plays an important role. Various factors influence the foraging behavior of worker bees such as weather, distance of food source from the hive, food quality, quantity of nectar and pollen. There is usually shortage of floral resources during summer and rainy seasons i.e. from June to August (Mishra and Sharma, 1997). Bees generally forage to a food source within 3 km radius. Foraging also depends upon temperature conditions as follows: no foraging (< 8°C); some activity (8°C-16°C); optimal condition (16°C-32°C); reduction in foraging, increase in water collection (> 32°C). Here we investigate pollen foraging activity of honeybees in autumn season.

Materials and Methods

The study was carried in a small apiary maintained at the Department of Zoology, Panjab University Campus, Chandigarh. Five colonies of *Apis mellifera* kept in Langstroth hives were taken for the study. To study the foraging activity of the honeybees, the number of pollen collecting foragers returning to the hive entrance was recorded for 5 minutes every one hour from 10:00 a.m. to 04:00 p.m. Observations were recorded twice a week from September-

November, 2011. Foraging efficiency of a colony was measured in terms of number of bees with pollen load entering the hive. The floral sources present near the colonies on which bees reached for pollen collection were observed. These observations were taken by naked eyes.

Results and Discussion

Pollen collection by honeybees: The bees efficiently collected pollen during the day time in autumn season. Pollen loads varied during the day showing hourly fluctuations. The worker bees had higher tendency to collect pollen in the morning and reduced their activity in late hours of the day (Table 1 and Fig. 1). It has previously reported that the foraging activity of all insect visitors was affected by environmental conditions such as temperature, light intensity, wind speed, and time of day and season (Kevan and Baker, 1983). Several workers investigated how such factors affected foraging activity and the general opinion was that the activity increased with temperature up to a threshold, above which visitation decreased (Hippa *et al.*, 1981; Willmer, 1983; Arroyo *et al.*, 1985; Boyle-Mackowski and Philogene, 1985; Gilbert, 1985).

Table 1: Mean number of pollen foragers per 5 minutes in five colonies.

S. No.	Time of Observations (September–November)	Mean number of pollen foragers per 5 minutes
1.	10:00	64.38 ± 18.67
2.	11:00	168.38 ± 21.31
3.	12:00	218.38 ± 33.27
4.	01:00	159 ± 22.03
5.	02:00	144.25 ± 37.14
6.	03:00	127.38 ± 33.48
7.	04:00	25 ± 9.59

p value is less than 0.0001, which implies results are statistically significant.

Pollen collection took place throughout the day. The rhythm of average number of pollen collecting foragers during day ranged from 218.38 ± 33.27 at 12:00 noon to 25 ± 9.59 at 4:00 p.m. After 03:00 p.m. the graph declined rapidly. This fluctuation was most likely due to fall in temperature. Louveaux (1958) observed that pollen was not collected when air temperature was below 10°C. Neupane and Thapa (2005) recorded that the number of pollen foragers was 62.3/colony during autumn when air temperature ranged from 34°C to 19°C and a relative humidity 85 to 87%. The air temperature played main role in influencing the worker bees to collect pollen.

Variety of floral sources present near the colony: There were many floral sources present near the colonies during autumn season on which honeybees reached for pollen collection. These floral sources were *Hibiscus rosa sinensis* (China rose), *Cassia siamea* (Golden shower), *Callistemon lanceolatus* (Bottle brush), *Eriobotrya japonica* (Loquat) but *Cassia siamea* was most abundant during the season. The pollen foragers collected maximum quantity of pollen from those plants which were more abundant in the area and lesser amount of pollen from those plants which were not very common.

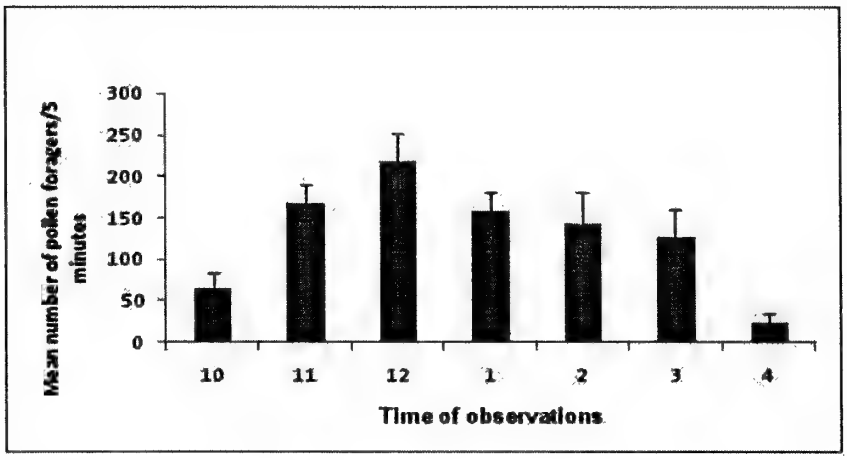

Fig. 1: Relationship between time of observation and mean number of pollen foragers per 5 minutes during autumn.

Conclusion

Maximum number of pollen collecting foragers was observed at 12:00 noon when air temperature ranged between 15°C to 32°C and *Cassia siamea* was the most abundant flora on which honeybees reached for pollen collection.

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HALTERES, Volume 4, 15-18, 2013

ISSN 0973-1555 © NAFISA AKHTAR AND M. NAYYAR AZIM

A Preliminary survey of thrips (Thysanoptera) from Kashmir Himalaya

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Abstract

A preliminary taxonomic survey has been conducted on Thrips of Kashmir region. The species collected have been systematically arranged in their respective families and subfamilies. The study is based on the personal collection of the senior author.

Keywords: *Thrips, taxonomic survey, Kashmir, India.*

Introduction

The thrips belong to the order Thysanoptera. They are tiny, slender insects with fringed wings. They are also referred to as bladder footed insects. Most of them are phytophagous and very few are known to be predaceous feeding mostly on mites, coccids, white ants and psocids. Besides, many species act as vectors and transmit a number of bacterial, fungal and viral diseases in plants (Sakimura, 1947; Mound, 1973; Reddy and Wightman, 1988 and Amin, 1980). Some species induce gall formation in the plant tissues. The rolled leave gall on *Piper* and *Ficus* trees are produced by few species in oriental region (Ananthakrishnan, 1978).

Some species of thrips are very useful and act as pollinators especially in oil palm (Syed, 1979). They also act as biological control agents (Lewis, 1973; Palmer and Mound, 1989 and Beattie, 1985).

In India significant contributions on the taxonomy of thrips have been made by Moulton (1929), Ananthakrishnan (1969a, 1969b, 1969c, 1971a, 1971b, 1973a, 1973b), Ananthakrishan and Sen (1980), Bhatti (1969a, 1969b, 1972, 1978, 1980, 1982, 1988, 1994, 1998, 2000, 2006), Bhatti and Mound (1980) and Mound (1976). A very little work has been carried out on this aspect from Kashmir region, however, important contributions include: Singh (1947) and Lone and Bhagat (1984).

In the present study a preliminary taxonomic survey has been conducted on Thrips of Kashmir region; the species are catalogued systematically under the respective suborders, families and genera.

SUBORDER TEREBRANTIA

Family Aeolothripidae

Genus: *Aeolothrips*

Aeolothrips collaris Priesner

Material examined: 5♀, 5 ♂, INDIA, Jammu and Kashmir, Srinagar, Shalimar garden on Zinnia, 4.viii.2010 (Nafisa Akhtar).

Aeolothrips fasciatus (Linnaeus)

Material examined: 8 ♀, 5 ♂, INDIA, Jammu and Kashmir, Srinagar, Shalimar garden on Zinnia, 4.viii.2010 (Nafisa Akhtar).

Family Thripidae

Genus: *Actinothrips*

Actinothrips rufus Haliday

Material examined: 6 ♀, 3 ♂, INDIA, Jammu and Kashmir, Srinagar, Botanical Garden, University of Kashmir on Dandelion, 20.iv.2010 (Nafisa Akhtar).

Genus: *Anaphothrips*

Anaphothrips obscurus (Muller)

Material examined: 4 ♀, 2 ♂, INDIA, Jammu and Kashmir, Budgam, Khanda on Saffron, 20.x.2010 (Nafisa Akhtar).

Genus: *Frankliniella*

Frankliniella intonsa Trybom

Material examined: 6 ♀, 5 ♂, INDIA, Jammu and Kashmir, Srinagar, Nageen lake on Lily, 17.ix.2010 (Nafisa Akhtar)

Frankliniella schultzei Trybom

Material examined: 4 ♀, 4 ♂, INDIA, Jammu and Kashmir, Srinagar, Nageen lake on Lily, 17.ix.2010 (Nafisa Akhtar).

Genus: *Microcephalothrips*

Microcephalothrips abdominalis (Crawfrod)

Material examined: 5 ♀, 5 ♂, INDIA, Jammu and Kashmir, Nehru Memorial botanical Garden on Marigold, 10.v.2010 (Nafisa Akhtar), 4 ♀, 6 ♂, Shalimar garden on Zinnia, 4.viii.2010 (Nafisa Akhtar).

Genus: *Megalurothrips*

Megalurothrips distalis (Karny)

Material examined: 7 ♀, 8 ♂, INDIA, Jammu and Kashmir, Srinagar, Shalimar garden on Roses, 23.v.2010 (Nafisa Akhtar), 5 ♀, 6 ♂, Botanical garden university of Kashmir on Dahlia, 23.vi.2010 (Nafisa Akhtar), 4 ♀, 3 ♂, Shalimar garden on Zinnia, 4.viii.2010 (Nafisa Akhtar), 5 ♀, 5♂, Budgam, Khanda on Saffron, 4.x.2010 (Nafisa Akhtar).

Megalurothrips pecularis (Bagnall)

Material examined: 6♀, 6 ♂, INDIA, Jammu and Kashmir, Srinagar, Shalimar garden on Roses, 23.v.2010 (Nafisa Akhtar), 5 ♀, 5 ♂, Shalimar garden on Zinnia 4.viii.2010 (Nafisa Akhtar).

Genus: *Heliothrips*

Heliothrips haemorrhoidalis (Bouche)

Material examined: 3 ♀, 4 ♂, INDIA, Jammu and Kashmir, Srinagar, Botanical garden university of Kashmir on Dandelion 20.iv.2010 (Nafisa Akhtar), 5 ♀, 5 ♂, Shalimar garden on Roses, 23.v.2010 (Nafisa Akhtar).

Genus: *Thrips*

Thrips tabaci Lindeman

Material examined: 6 ♀, 5 ♂, INDIA, Jammu and Kashmir, Srinagar, Indira Gandhi memorial Tulip garden on Tulips, 24.iv.2010 (Nafisa Akhtar), 3 ♀, 4♂, University of Kashmir botanical garden on Marigold, 10.v.2010 (Nafisa Akhtar), 4 ♀, 4♂, Nageen lake on lily, 17.ix.2010 (Nafisa Akhtar).

Thrips flavus Schrank

Material examined: 3 ♀, 3 ♂, INDIA, Jammu and Kashmir, Srinagar, Nehru memorial botanical garden on Roses, 10.v.2010 (Nafisa Akhtar), 4 ♀, 6 ♂, Shalimar garden on Roses, 4.vi.2010 (Nafisa Akhtar).

Thrips coloratus Schmutz

Material examined: 7 ♀, 7 ♂, INDIA, Jammu and Kashmir, Nehru memorial botanical garden on Roses, 10.vi.2010 (Nafisa Akhtar), 4 ♀, 3 ♂, Shalimar garden on Zinni, 4.vii.2010 (Nafisa Akhtar).

Thrips nigropilosus Uzel

Material examined: 6 ♀, 5 ♂, INDIA, Jammu and Kashmir, Srinagar, Gulmarg on *Chrysanthemum*, 17.vii.2010 (Nafisa Akhtar).

Thrips trehernei Priesner

Material examined: 5 ♀, 5 ♂, INDIA, Jammu and Kashmir, Srinagar, University of Kashmir botanical garden on Dandelion, 20.iv.2010 (Nafisa Akhtar), 4 ♀, 3 ♂, Shalimar garden on Roses,23.v.2010 (Nafisa Akhtar).

Thrips hawaiiensis (Morgan)

Material examined: 3 ♀, 4 ♂, INDIA, Jammu and Kashmir, Srinagar, Indira Gandhi memorial Tulip garden on Tulips, 24.iv.2010 (Nafisa Akhtar), 3 ♀, 3 ♂, University of Kashmir botanical garden on Marigold, 10.v.2010 (Nafisa Akhtar), 2♀, 2♂, Nageen lake on Lily, 17.ix.2010 (Nafisa Akhtar).

Thrips simplex (Morison)

Material examined:8 ♀, 4 ♂, INDIA, Jammu and Kashmir, Srinagar, Dal lake on Lotus, 17.ix.2010 (Nafisa Akhtar), 3 ♀, 2 ♂, Ganderbal, floriculture farm house on Gladiolus,23.vi.2010 (Nafisa Akhtar).

Genus: *Scirtothrips*

Scirtothrips dorsalis Hood

Meterial examined: 5 ♀, 5 ♂, INDIA, Jammu and Kashmir, Srinagar, Nehru memorial botanical garden on Marigold, 10.v.2010 (Nafisa Akhtar), 4 ♀, 3 ♂, Shalimar garden on Zinnia 4.viii.2010 (Nafisa Akhtar).

Family Phlaeothripidae

Genus: Haplothrips

Haplothrips robustus Bagnall

Material examined: 3 ♀, 2♂, INDIA, Jammu and Kashmir, Budgam, Khanda on Saffron 20.x.2010 (Nafisa Akhtar).

Haplothrips verbasci (Osborn)

Material examined: 4 ♀, 5 ♂, INDIA, Jammu and Kashmir, Budgam, Khanda on saffron, 20.x.2010 (Nafisa Akhtar).

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ISSN 0973-1555 © MANPREET S. PANDHER AND MALKIAT S. SAINI

Addition of a new species to *Ecnomus* McLachlan, 1864 (Trichoptera: Ecnomidae) along with key to its Indian Fauna

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Abstract

A new species is added to the Ecnomid fauna of India. The newly described species *Ecnomus suni* sp. nov. is recorded from Cherrapungee (Meghalaya). In addition, a key to the males of Indian species of *Ecnomus* is provided.

Keywords: *Ecnomidae, India, Himalaya, Meghalaya.*

Introduction

The type genus *Ecnomus* McLachlan was the only genus included in Ulmer's (1903) Hydropsychidae under subfamily Ecnominae (now Ecnomidae). The Ecnomidae now includes 7 genera: *Ecnomus* McLachlan, *Daternomina* Neboiss, *Ecnomina* Kimmins, *Austrotinodes* Schmid, *Absensomina* Cartwright, *Wellsomina* Cartwright and *Neboissomina* Cartwright. The record of species diversity of *Ecnomus* McLachlan has increased many folds during the past 22 years. According to Cartwright (1990) the genus had only 130 species; within a span of only seven years Li and Morse (1997) gave this figure as 221 species. This number swelled up to 275 species as reported by Johanson and Espeland (2010) and at present this figure stands at 280 species (Morse, 2012). Side by side there is a rapid increase in the knowledge of females and the larvae of most genera of Ecnomidae (Cartwright, 1990, 1997, 2008, 2009, 2010 and 2011). It was Li and Morse (1997) who applied the cladistic principles to this family and traced the phylogeny of Chinese species of this genus. As far as oriental region is concerned most of the contributions are by Malicky (1979, 1993, 1995a, 1995b, 1997, 2000, 2007, 2008 and 2009); Malicky and Chantaramongkol (1993a, 1993b) and Malicky *et al.* (2004 and 2006) who described many species from Bhutan, Srilanka, Vietnam, Nepal, Thailand, China, Laos, Indonesia (Bali, Kalimantan, Sumatra, Sulawesi), Malaysia, Myanmar and India (Andaman and Nicobar).

From the Indian region only 7 species are on record. Mosely (1932) was the first to describe 3 species from India. He was followed by Martynov (1935) with 3 species. Malicky (1979) reported 1 new species of this genus from Andaman Island. It is nearly 33 years or so that no contribution has been made to this genus from India. In this paper a new species is described and illustrated along with the key to the males of Indian species.

Materials and Methods

Adults were collected by light traps (UV and mercury vapour bulb) placed near

the edge of high altitude streams of the Himalayan belt of India. The specimens were preserved in 70% ethyl alcohol with a drop of glycerol added. Pertinent collection and locality data were recorded.

The male genitalia were removed from the specimens and put in 10% KOH solution overnight. After this treatment the genitalia were put in 80% ethyl alcohol with a drop of glycerol and observed for morphological characters. The drawings of various aspects were done with the aid of a stereoscope (maximum magnification of 160X) fitted with an ocular grid in one eye piece. The final drawings were rendered in black ink. The illustrations were scanned at 600 dpi grayscale, and mounted onto plates in Adobe© Photoshop© 7.0. The genitalic terminology corresponds to Li and Morse (1997). Type specimens are deposited in the Punjabi University Patiala Museum (PUPM), Department of Zoology and Environmental Sciences, Punjabi University, Patiala.

Systematics

Ecnomus McLachlan, 1864: 26, 30.

Type species: *Philopotamus tenellus* Rambur 1842: 503 (monobasic).

Synonymy:

= *Ecnomiella* Mosely, 1935: 221-222.

Type species: *Ecnomiella bifurcata* Kimmins (original designation).

Kimmins, 1957: 261 as footnote (as synonym of *Ecnomus*)

Diagnosis: Maxillary palpi 5 segmented, its 2nd segment slightly longer than 1st but shorter than 3rd as well as 4th; 3rd segment positioned apically on 2nd; 5th segment longest, secondarily annulated and flexible. Forewings each with fork of R_1, forks I, II, III, IV, and V and discoidal cell, median cell, and thyridial cell; corneous nygmae in F-II and thyridial cell. Few species with fork of R_1 very faded and fork-I absent. Fork IV sessile. Hind wing with forks II and V and without discoidal cell, median cell, or rc. Fork II without nygma.

***Ecnomus suni* sp. nov.**

(Figs. 1-4)

Material examined: Holotype: ♂, India: Meghalaya; Cherrapungee, 1200 m, 26-v-2011, Pandher, (PUPM), Ref. no. TRC/E/11.

Paratype: Collection data same as of holotype, 1♂, 1♀, (PUPM), TRC/E/12, TRC/E/13.

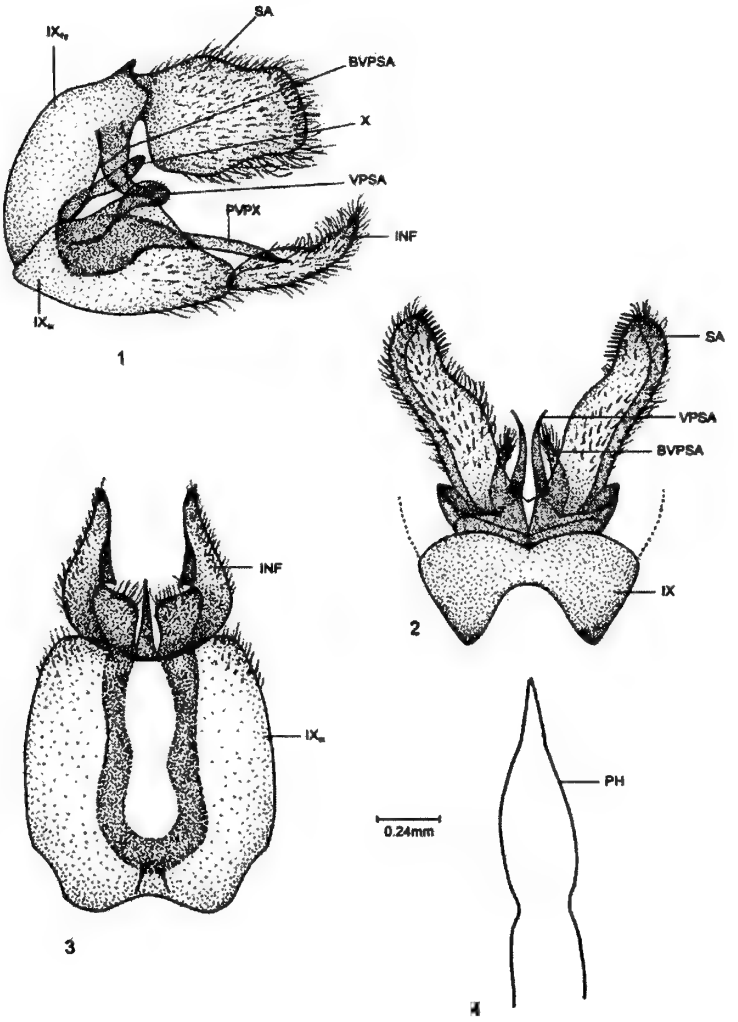
Description: Adult ♂; color in alcohol brown, dorsum of head dark brown. Length from tip of head to apex of folded forewing about 6mm; maxillary palp 1.50 mm, 4th segment longer than 2nd as well as 3rd, 5th longest; labial palp small 0.50mm long. Length of forewing 4.75 mm; venation typical for genus. Hind wing about 3mm long.

Male genitalia (Figs. 1-4): Anterior margin of sternum IX roundly produced, broad ventrolaterally; tergum IX broad, anterolaterally convex, pointed dorsoapically. Segment X lobe like, its posteroventral projection slender, expanded laterally in the middle. Superior appendage broad, quadrate and smaller than inferior appendages in lateral view, with small baso-ventral projection. Inferior appendages almost straight, at mesal margins in ventral view with mesal concavity at middle and with small mesal projection beyond this concavity, sharp at apex. Phallus sharp at apex, protruding laterally at middle.

Diagnosis: *Ecnomus suni* sp.nov. is allied to *E. thogarma* Malicky and Chantaramongkol, 2009 and *E. venimar* Malicky and Chantaramongkol, 1993a. The shape of inferior appendages in ventral view is close to *E. thogarma* but the shape of superior appendages differs in lateral view from the latter. In lateral view *E. suni* is more close to *E. venimar* because of the shape of superior appendages. However, *E. suni* is a distinct species as it differs in the shape of inferior appendages in ventral view from *E. venimar.*

Distribution: India: Meghalaya.

Etymology: This species is named in honour of Sun Changhai who is working on Chinese Trichoptera.



Figs. 1-4. ***Ecnomus suni*** **sp. nov., male genitalia. 1- left lateral view, 2- dorsal view, 3- ventral view, 4- Phallus ventral view. (IX_{Tg} – Tergum IX, IX_{St} – Sternum IX, SA – Superior appendage, BVPSA – Baso ventral projection of Superior appendage, X – Segment X, VPSA – Ventral projection of Superior appendage, PVPX – Postero ventral projection of X, INF – Inferior appendage, IX – Segment IX, PH – Phallus)**

Key to the males of Indian species of genus *Ecnomus* McLachlan

1. Superior appendage pointed at apex in lateral view.....***E. costalis*** **Martynov**
- Superior appendage not pointed at apex in lateral view (Fig. 1).....2
2. Superior appendage rounded apically in lateral view (Fig. 1).....3
- Superior appendage truncate apically in lateral view.....***E. pusanus*** **Mosely**
3. Inferior appendages longer than superior appendages in lateral view (Fig. 1).....4
- Inferior appendages shorter than superior appendages in lateral view....7
4. Sternum IX broad apically in lateral view.....***E. moselyi*** **Martynov**
- Sternum IX narrow apically in lateral view (Fig.1).....5
5. Inferior appendage with very thin slender process at base; the former is very slender in lateral view .....***E. indicus*** **Martynov**
- Inferior appendage without thin slender process at base; and it is not slender in lateral view (Fig. 1).....6
6. Superior appendage very long and broad in its dorsal view; its upper distal margin not pointed (Fig. 2).....***E. suni*** **sp. nov.**
- Superior appendage small and broad in its dorsal view; its upper distal margin pointed.....***E. fletcheri*** **Mosely**
7. Inferior appendage with an angular projection on dorsal side about midway and directed towards base in lateral view.....***E. montanus*** **Mosely**
- Inferior appendage smooth without any angular projection on dorsal side in lateral view.....***E. mithraki*** **Malicky**

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On the Aphid–ant association and its relationship with various host plants in the Agroecosystems of Vadodara, Gujarat, India

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Abstract

Aphid-ant association and its relationship with various host plants is age old and in most of the cases remains unreported. The present research deals with the extent of damage caused by aphids, a major pest of economically important crops. It also focuses on the role of ants in spreading this pest from one crop to another in the agroecosytems of Vadodara. Hence the objectives of the present study were: to identify the aphid species infesting various agricultural crops with an aim to control them; and to identify ants and host plants associated with the aphid species. Three species of aphids, *Aphis crassivora, A. gossypii* and *A. nerii* were collected from the fields and later identified. Ants associated with aphids were *Camponotus compressus, Monomorium minimum, Pheidole* sp. and *Solenopsis* sp. The ant *Camponotus* sp. usually acts as one of the main cause of spread of aphids from one plant to another. Aphid–ant association was seen in 30 economically important crops maximally from the families Malvaceae, Fabaceae, Solanaceae and Brassicaceae. Ant–aphid association if disrupted can control the population of aphids in the agricultural fields. Therefore, the management of ants can be added as a key component in management of serious pests like aphids.

Keywords: *Aphid-ant association, agroecosystems.*

Introduction

Aphids (Homoptera: Aphidoidea) and ants (Hymenoptera: Formicidae) are the protagonists of one of the most studied model of mutualistic relationships in the animal kingdom (Detrain *et al.*, 2010). This aphid–ant association has strong interaction with various host plants. Aphids are one of the major pests of the economically important crops of Vadodara like cotton, castor, pigeon pea, cow pea, etc. Razaq *et al.* (2011) reported 10-90% yield loss in India to the economically important crops depending upon severity of damage and crop stage by aphids.

It is a well-known fact that an ant colony tends simultaneously several aphid species, thus there can be intra or interspecific competition between aphid groups for the services of ants. Aphids produce a carbohydrate and nitrogen rich excretion called as honeydew, which is collected by ant species; in return provide protection and hygiene to aphids. This in popular terms is known as mutual interaction.

In India, few cases on aphid–ant association have been reported, but none from Vadodara agricultural fields. Keeping this in mind, the present study was conducted

on aphid–ant association and its relationship with various host plants in and around agricultural fields of Vadodara. The main objectives of the work were to: 1) identify the aphid species infesting various agricultural crops with an aim to control them. 2) identify ants and host plants associated with aphid species.

Materials and Methods

Study was conducted from September 2008 to May 2011. Survey sites were chosen on the basis of accessibility and location within an eco-region. Vadodara District is located in the eastern part of the state of Gujarat in western India at 22°17'59''N, 73°15'18''E, 35 m above the sea level. Aphid infestation was studied in agricultural fields of Vadodara, located within 80 kms of Vadodara city. All fields were approximately 2-5 ha in size. The main crops cultivated are Cotton, Castor, Sugar cane, Pigeon pea, Chickpea, Ladies finger, Potato, Brinjal, Radish, Cauliflower, Wheat, Paddy and Maize.

Collection of female aphids was done by hand collection from aphid infested plants. For collection of ants pitfall and hand collection methods were used, collected specimens were preserved in 70% alcohol for laboratory identification. A stereomicroscope, Leica MPS 60 Ø28/8x/MPS was used for identification and photographic record. Photography was done using a Canon digital camera (Power Shot ISI-120, 12x optical zoom). Aphids were identified using Blackman and Elastop (2000) and later confirmed in the Entomology Division of the Anand Agricultural University Anand. Ants were identified using the keys provided by Bolton (1994). The identification of host plant species were done by Department of Botany, The Maharaja Sayajirao University of Baroda.

Assessment of incidence and infestation rate of aphids

The assessment of infestation by insect pests on various crops was done as per the **"1-4 Scale infestation"** scale (Nagrare *et al.*, 2011).

a) 1 Grade: Scattered appearance of few aphids on the plant.
b) 2 Grade: Severe infestation of aphids on any one branch of the plant.
c) 3 Grade: Severe infestation of aphids on more than one branch or half portion of the plant.
d) 4 Grade: Severe infestation of aphids on the whole plant.

Results and discussion

The incidence of aphid population on various host plants was observed from September 2008 to May 2011. Infestation of aphids start appearing in the month of September. As the crop grows, population of the aphids on the crop also increases. Maximum population of aphids was observed in the months of November to January which gradually starts decreasing in the months of February and March. Aphid population disappears totally in the month of April to reappear again in September. This was the observation for all the three consecutive years in agricultural fields of Vadodara. Karim *et al.* (2001) also reported that the aphid population started growing from August, became highest in January and almost vanished in April.

Our results clearly show that aphids are polyphagous and cause severe damage to many host plants (Table 1). In Vadodara, 30 host plant species were recorded from 17

different families. Takalloozadeh (2010) from Iran also reported *Aphis gossypii* attacking more than 70 different host plants. Major hosts of the aphids in agriculture fields of Vadodara are *Gossypium arboreum*, *Vigna unguiculata*, *Solanum tuberosum* and *Solanum melongena*. Whereas ornamental plants such as; *Hibiscus mutabilis*, *Hibiscus rosa-sinensis*, *Nerium indicum*, *Chrysanthemum* sp. and certain weeds like *Calotropis procera* worked as alternative host of aphids. Plant species belonging to family Malvaceae (17%), Fabaceae (16%), Solanaceae (12%) and Asclepiadaceae (10%) were found as preferred host plants of aphids in Vadodara (Fig. 1).

Aphid–ant interaction is commonly seen on various host plants; about 30 host plants and 6 species of aphids namely *Aphis brassicae*, *A. crassivora*, *A. fabae*, *A. gossypii*, *A. nerii*, *Myzus persicae* were recorded from Vadodara agricultural sites (Table 2). Most abundant species considered as major pests in Vadodara include *Aphis gossypii*; *Aphis crassivora* and *Aphis nerii*. Ants commonly associated with aphids involve *Camponotus compressus*, *Pheidole* sp., *Monomorium* sp. and *Solenopsis* sp.

A. brassicae was mostly seen on the Brassicaceae family (cabbage and cauliflower) with *Pheidole* ants associated with them. *A. crassivora* was mainly found on the family Fabaceae, Malvaceae and Lamiaceae with ants *Camponotus compressus* and *Monomorium minimum* associated with them. Along with these ants; the family Lamiaceae also had association with ant *Lasius niger* which is rarely seen in other host plants. *A. fabae* mostly seen on the family Fabaceae, Solanaceae, Asteraceae, Amaranthaceae and Papaveraceae in association with ants *Camponotus compressus* and *Monomorium* sp. But in Solanaceae and Papaveraceae, ants *Pheidole* sp. and *Solenopsis* sp. were also seen.

In Vadodara agricultural fields, *A. gossypii* is one of the major threats to Cotton. *A. gossypii* was mainly found on Malavaceae, Solanaceae and Asteraceae family having strong interaction with *Camponotus compressus*, *Monomorium* sp. and *Pheidole* sp. Patel *et al.* (2011) reported that 1326 insect species damage Cotton (*Gossypium* spp.) in approx. 100 countries, of which 16 species are of major concern causing an annual loss of 50-60% of the total production in Northern Gujarat. The ratio of ants and aphids per plant on cotton crops was found to be 1:30. Whereas *A. nerii* was also associated with the *Camponotus compressus* on *Nerium* and *Calotropis* plants; ant *Monomorium* sp. was found on the family Asteraceae and Amarantheceae and the *Solenopsis* sp. was on the family Rutaceae and Poaceae. *Myzus persicae* mainly seen on the family Malvaceae, Brassicaceae, Amarantheceae and Solanaceae and the associated ants are *Camponotus compressus* and *Monomorium* sp. In spinach and brinjal, aphid association was seen with *Solenopsis* sp. and *Pheidole* sp.

The species of ants such as *Camponotus compressus*, *Pheidole* sp. and *Monomorium* sp. was seen on aphids on different crops but *Camponotus compressus* being the major one. Thus, the aphid association is commonly seen with *Camponotus compressus* and *Monomorium* sp. The host plants were varying but the aphid–ant association remains the same. Maximum aphid – ant association was found on cotton crop along with beans and pigeon pea. But less association of aphid–ant interaction were seen on Brassicaeae and Utriaceae.

A mutual interaction was observed between aphids and ants. Aphids produce honeydew excretion which is a food for ants and ants gives protection to aphids. In Ankara Plant Protection Central Research Institute of Turkey, Ozdemir *et al.* (2008) reported 16 different species of ants associated with 19 aphid species. The most encountered ant species associated with many aphid species were *Camponotus aethiops*, *Camponotus piceus*, *Formica glauca*, *Lasius paralienus* and *Crematogaster ordidula*. In Vadodara district, *Pheidole* sp. and *Camponotus compressus* were observed tending aphid colonies on many plants. Vinson and Scarborough (1989) also found out the presence of few red imported fire ants, *Solenopsis invicta* workers on aphid bearing cotton plants reduced aphid predators effectiveness in laboratory. *Camponotus compressus* was generally found on almost all the host plants, generally acting as a carrier could most possibly be one of the reasons of aphid dispersion from one plant to other host plant in Vadodara. Hence the present study persuades us to study more about these associated relationships and for understanding of the patterns and processes associated with aphid-ant relationships.

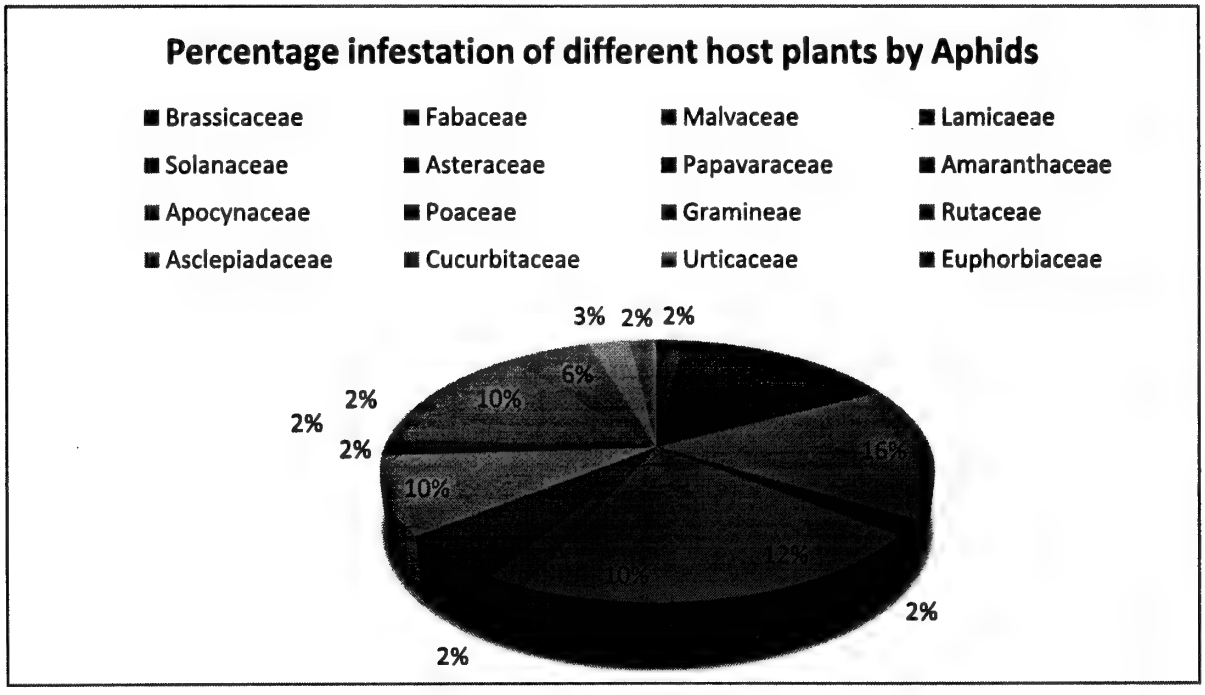

Fig. 1: Percentage infestation of different host plants by aphids.

Table 1: Host plants of Aphids with its infestation level in agrosystem of Vadodara.

Host category	Botanical Name	Common Name	Family	Infestation Scale
Field crops	*Gossypium hirsutum* (L.)	Cotton	Malvaceae	4 Grade
	Ricinus communis (L.)	Castor	Euphorbiaceae	1 Grade
	Cajanus cajan (L. Millsp.)	Pigeon pea	Fabaceae	4 Grade
	Vigna unguiculata (L.)	Cow pea	Fabaceae	4 Grade
	Zea mays (L.)	Maize	Poaceae	2 Grade
	Triticum aestivum (L.)	Wheat	Gramineae	2 Grade
Vegetables	*Solanum melongea* (L.)	Brinjal	Solanaceae	3 Grade
	Solanum tuberosum (L.)	Potato	Solanaceae	3 Grade
	Lycopersicon esculentum (L.)	Tomato	Solanaceae	4 Grade
	Abelmaschus esculentus (L.)	Lady's finger	Malvaceae	4 Grade
	Brassica oleracea (Linn)	Cabbage	Brassicaceae	2 Grade
	Beta vulgaris (L.)	Beet	Papaveraceae	0 Grade
	Cucumis sativus (L.)	Cucumber	Cucurbitaceae	2 Grade
	Spinacia oleracea (L.)	Spinach	Amarathaceae	2 Grade
	Raphanus sativus(L.)	Radish	Brassicaceae	2 Grade
Ornamental crops/ Fruit trees/trees and shrubs	*Nerium indicum* (Mill.)	Oleander	Apocynaceae	2 Grade
	Tagetes erecta (L.)	Marigold	Asteraceae	1 Grade
	Hibiscus mutubilis (L.)	Cotton rose-mallow	Malvaceae	3 Grade
	Hibiscus rosa-sinensis (L.)	China rose	Malvaceae	4 Grade
	Ocimum sanctum (L.)	Tulsi	Lamiaceae	1 Grade
	Helianthus annuus (L.)	Tulsi	Asteraceae	1 Grade
	Papaver somniferum (L.)	Opium poppy	Amaranthaceae	0 Grade
	Rosa indica (L.)	Rose	Rosaceae	1 Grade
	Atriplex rosea (L.)	Red orach	Asteraceae	0 Grade
	Matricaria recutita (L.)	Chamomile	Asteraceae	0 Grade
	Nerium oleander (L.)	Oleander	Apocynaceae	4 Grade
	Vinca rosea (L.)	Periwinkle	Apocynaceae	1 Grade
	Citrus limonium (L.)	Lemon	Rutaceae	2 Grade
	Chrysanthemum sp. (L.)	Chrysanths	Asteraceae	3 Grade
	Urtica dioica (L.)	Stinging nettle	Urticaceae	0 Grade
Weeds	*Datura metel* (L.)	Angel's trumpet	Solanaceae	0 Grade
	Chenopodium album (L.)	Pigweed	Asteraceae	1 Grade
	Cirsium arvense (L. Scop)	Canada thistle	Asteraceae	1 Grade
	Calotropis procera (W.T.Aiton)	Apple of sodom	Asclepiadaceae	4 Grade
	Gomphocarpus sp. (E.mey.)	Cotton bushes, Balloon bushes	Asclepiadaceae	2 Grade
	Asclepias (E.mey.)	Butterfly weed	Asclepiadaceae	2 Grade

Table 2. Aphid- Ant association and their host plants in the agricultural fields of Vadodara

APHIDS	FAMILY	HOST PLANTS	ANTS
Aphis brassicae (Linnaeus ,1758)	*Brassicaceae*	*Brassica oleracea* (Linn) (Cabbage)	*Pheidole* sp.
Aphis crassivora (Koch, 1854)		Leguminous crops	
	Fabaceae	*Cajanus cajan* (L. Millsp.) (Pigeon pea)	*Camponotus compressus*
	Fabaceae	*Vigna unguiculata* (L.) (Cow pea/ Beans)	*Camponotus compressus* *Monomorium minimum*
	Malvaceae	*Hibiscus rosasinesis* (L.) (China rose)	*Camponotus compressus* *Monomorium minimum*
	Lamiaceae	*Ocimum sanctum* (L.) (Tulsi)	*Monomorium minimum* *Lasius niger* *Camponotus compressus*
Aphis fabae (Scopoli,1763)	*Fabaceae*	*Vigna unguiculata* (L.) (Cow pea/Beans)	*Camponotus compressus* *Monomorium* sp.
	Solanaceae	*Solanum tuberosum* (L.) (Potato)	*Camponotus compressus* *Pheidole* sp.
	Asteraceae	*Helianthus annuus* (L.) (Sun flower)	*Monomorium minimum*
	Solanaceae	*Solanum lycopersicum* (L.) (Tomato)	*Monomorium* sp.
	Papaveraceae	*Beta vulgaris* (L.) (Beet)	*Monomorium* sp.
	Amaranthaceae	*Papaver somniferum* (L.) (Opium Poppy)	*Solenopsis* sp. *Monomorium* sp.
	Asteraceae	*Chenopodium album* (L.) (Lamb's quarters/Pigweed)	*Monomorium minimum*
	Asteraceae	*Atriplex rosea* (L.) (Red orach)	
		Matricaria recutita (L.) (Chamomile)	
		Cirsium arvense (L.Scop) (Canada thistle)	
Aphis nerii (Boyer de Fonscolombe , 1841)	*Apocynaceae*	*Nerium oleander* (L.) (Oleander)	*Camponotus compressus*
	Apocynaceae	*Vinca* sp. (L.) (Periwinkle)	*Monomorium minimum*
	Poaceae	*Zea mays* (L.) (Maize)	*Solenopsis* sp.
	Gramineae	*Triticum aestivum* (L.) (Wheat)	*Solenopsis* sp. *Monomorium* sp. *Camponotus compressus*
	Rutaceae	*Citrus limonium* (L.) Burm.f. (Lemon)	*Solenopsis* sp.
	Asclepiadaceae	*Calotrophis* sp.(R.Br.) (Milkweed)	*Camponotus compressus*
	Asclepiadaceae	*Gomphocarpus* sp. (E.mey.) (Cotton bushes, Balloon bushes)	*Camponotus compressus*
	Asclepiadaceae	*Asclepias* (E.mey.) (Butterfly weed)	*Camponotus compressus*

Table 2: continued

Aphis gossypii (Glover, 1877)	*Malvaceae*	*Gossypium* sp. (L.) (Cotton)	*Camponotus compressus*
	Solanaceae	*Solanum melongena* (L.) (Brinjal)	*Camponotus compressus* *Pheidole* sp.
	Cucurbitaceae	*Cucumis sativus* (L.) (Cucumber)	*Camponotus compressus*
	Malvaceae	*Hibiscus rosa sinensis* (L.) (China rose)	*Monomorium minimum* *Camponotus compressus*
	Asteraceae	*Chrysanthemum* sp. (L.) (Chrysanths)	*Monomorium minimum* *Camponotus compressus*
	Urticaceae	*Urtica dioica*.(L.) (Stinging nettle)	*Solenopsis* sp.
Myzuspercicae (Sulzer, 1758)	*Malvaceae*	*Gossypium* sp. (L.) (Cotton)	*Camponotus compressus* *Solenopsis* sp.
	Amaranthaceae	*Spinacia oleracea* (L.) (Spinach)	*Monomorium* sp. *Camponotus* sp. *Pheidole* sp.
	Brassicaceae	*Brassica oleracea* (Linn) (Cabbage)	*Monomorium* sp.
	Brassicaceae	*Raphanus sativus* (L.) (Radish)	*Camponotus compressus*
	Solanaceae	*Solanum melongena* (L.)	*Pheidole* sp.

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ISSN 0973-1555 © PRADEEP D'CUNHA AND VIJAY MALA GROVER NAIR

Diversity and Distribution of Ant Fauna in Hejamadi Kodi Sandspit, Udupi District, Karnataka, India

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Abstract

Ants are highly diverse and successful in varied habitats. The present study records diversity and distribution of ant fauna in Hejamadi Kodi sandspit (13° 04' to 13° 05' N latitude and 74° 46' E longitude) located in Udupi district, west coast of Karnataka during November and December, 2011. The spit is 1.2 km long with an area of 0.332 km^2. The river Shambavi flows along the east side of the spit parallel to the Arabian sea and joins the sea on the southern end of the spit. The temperature and humidity ranges from 22° to 33°C and 86 to 90 % respectively. The ant samples were collected using random transects following all out search, bait and pit-fall methods from each demarcated area categorized on the basis of nature of vegetation complex as zone (I) - sandy beach; (II-A) - thick creepy vegetation with scanty shrubs and (II-B) - thin creepy vegetation with moderate number of shrubs; (III) - mixed vegetation with wild and planted flora; (IV) - mangroves and (V) - coconut plantation. A total of 31 species belonging to 17 genera have been placed under five subfamilies (Formicinae, Myrmicinae, Ponerinae, Dolichoderinae and Pseudomyrmecinae). The data on distribution of ants records the highest number of species in zone IIIrd, followed by Vth, IIA, IIB, and IVth. The alpha diversity index values suggest that zone Vth is more diverse and have even distribution of ant species which probably may be attributed to the varied vegetation type; soil attributes in particular the temperature and the calcium carbonate level among the demarcated zones. However, the exclusive absence of ants specifically in the sandy beach zone may be attributed to constant tidal influx and the total absence of any kind of vegetation.

Keywords: *Ant fauna; Biodiversity indices; Coastal habitat; India; Sandspit; Karnataka.*

Introduction

The coastal area is one of an important zone of the terrestrial ecosystem. The coastal habitats are typically known to harbor rich biodiversity. Ants are considered useful for monitoring as they are abundant and ubiquitous in both intact and disturbed areas (Andersen, 1990; Pearson, 1994; Andersen, 1997; Folgarait, 1998; Hoffman *et al.*, 2000; Delabie *et al.*, 2006).

Earlier studies documenting the presence of ants in the coastal environment have recorded the effects of fire ants on sea turtle nesting beaches in Florida and on neonatal American alligator in the southeastern United States (Allen *et al.*, 2001a, b). A few ants, *Iridomyrmex pruinosus analis* and *Brachymyrmex depilaris* have been documented strictly intertidal

from the Gulf of California, Mexico (Yensen *et al.,* 1980; Maitland and Maitland, 1994). A study reporting diversity and habitat preferences of ant assemblages in Department of Atomic Energy (DAE) campus Kalpakkam situated on southeast coast of India suggests that scrub jungle and riparian woods are most diverse habitat followed by the monoculture and sandy area indicating that vegetation type, soil characteristic and anthropogenic disturbances influence the ant assemblage (Ramesh *et al.,* 2010).

The west coastal segment along Dakshina Kannada and Udupi district represents spits of different sizes and shapes. A spit or sandspit is a ridge or embankment of sediment attached to the land at one end and terminates into the open water at the other end (Evans, 1942). Ants play an important role in soil turnover and the nutrient recycling (Lal, 1988). There is no report documenting ant faunal diversity and distribution in the specialized habitats of the coastal spits. The present study, therefore aimed to record diversity and distribution of ant fauna in Hejamadi Kodi spit, Udupi district, Karnataka, India.

Material and Methods

The Hejamadi spit situated (between 13° 04' to 13° 05' N latitude and 74° 46' E longitude) in the southern part of Udupi district, west coast of Karnataka, India (Fig. 1) is 1.2 km in length with an area of 0.332 km^2. The river Shambavi flows along the east side of the spit parallel to the sea and joins Arabian sea on the southern end of the spit. The climate of the study area is warm, humid and receives an annual rainfall of about 160 inches. The temperature and humidity ranges from 22°-33°C and 86-90% respectively. The study area was demarcated into five zones based on the presence of predominant type of vegetation viz. (I) - sandy beach – no vegetation covering an area of about 5.261 ha; (IIA) - thick creepy vegetation with scanty shrubs covering an area of 5.6 ha and (II B) - thin creepy vegetation with moderate number of shrubs covering an area of 4.6 ha; (III) – mixed vegetation covering an area of 14.75 ha having wild and planted flora; (IV) – mangroves plants with an area of 0.479 ha and (V) – coconut plantation covering an area of about 2.5 ha (Fig. 1).

The samples were collected during November and December, 2011 using random transects of 10 x 10 m in each demarcated zone. Various methods employed for collection of the ant fauna includes all out search (hand collecting), pitfall and bait methods. Plastic cups (9 cm in diameter and 15cm in length) filled with ethylene glycol (5%) as the killing agent were kept in the center of transect. Dry coconut, sugar, honey and fried items were used as baits, placed at the four corner of the each transect. The collected ant samples were persevered in 70% alcohol and identified using appropriate keys (Bingham, 1903; Bolton, 1994). The floral species encountered are listed in Table 1. The abiotic parameters (pH, salinity, calcium carbonate, total organic matter moisture content, air and soil temperature) of the different zones were recorded (Trivedy and Goel, 1986). The coordinate readings were noted down using global positioning system (GPS). The alpha diversity indices were obtained using Shannon's index (H'), Simpson's index of diversity (1-D) and Shannon's equitability (J) index using Past software ver. 2.17b (Hammer *et al.,* 2001) whereas β – diversity indices were obtained using Jaccard's and Bray – Curtis similarity coefficient values using Estimate S version 8.20 (Colwell 2004).

Results

The study area was demarcated into five zones based on the presence of predominant type of vegetation as (I) sandy beach with no vegetation; (II A) thick creepy vegetation with scanty shrubs and (II B) thin creepy vegetation with moderate number of shrubs; (III) mixed vegetation having wild and planted flora; (IV) mangroves and (V) coconut plantation. The ants collected from Hejamadi Kodi spit area in present study records the presence of a total of 31 species placed under 17 genera and 5 subfamilies (Table 2). The number of ant species placed under subfamily Myrmicinae counts highest (17) followed by Formicinae (9), Ponerinae (3) and one each under Dolichoderinae and Pseudomyrmicinae. The number of subfamilies recorded in the study area represents the presence of four subfamilies in IIIrd and three subfamilies each in IInd, IVth and Vth zones (Fig. 2). The overall percent distribution of subfamilies records the highest representation of subfamily Myrmicinae (55%) followed by Formicinae (32%), Ponerinae (7%), Dolichoderinae and Pseudomyrmicinae (3% each) (Fig. 2). The zone wise record lists the highest number of ant species in IIIrd followed by Vth, IIA, IIB, IVth and the total absence of ants in the Ist zone (Table 2). The genus *Tetramorium* is represented maximally (5 species) followed by *Monomorium* (4 species), *Camponotus* and *Crematogaster* (3 species each) and *Tapinoma* and *Tetraponera* (only one species each) in the study area (Table 2).

The species wise distribution of ants in the demarcated zones indicates the presence of *Paratrechina longicornis* and *Crematogaster subnuda* in all the four vegetative zones. Whereas, *Plagiolepis jerdonii*, *Camponotus compressus*, *Nylanderia* sp.1 and *Monomorium orientale* species were seen only in three vegetative zones (II, III and V) and certain ant species *Anochetus* sp. 1, *Camponotus sericeus*, *Camponotus oblongus*, *Crematogaster* sp. 2, *Diacamma* sp. *Meranoplus bicolor* and *Tetramorium obesum* were recorded only in zone Vth. On the other hand *Anoplolepis gracilipes*, *Crematogaster* sp. 1, *Nylanderia* sp. 2, *Oecophylla smaragdina*, *Tetramorium* sp. 1 and *Tetramorium* sp. 2 were restricted only in zone IIIrd, whereas *Tetraponera nigra* was recorded only in zone IVth (Table 2). Further the association of ant species with plant taxa was also found to vary. Eleven ant species were confined to the specific plant taxa whereas ten species were encountered on more than one plant taxa (Figs. 3).

The number of ant nests recorded also varied in different zones (Table 2; Fig. 4). The total number of ground nests encountered was highest in zone IIA followed by IIIrd, IIB and the least in zone Vth. Whereas the *Crematogaster subnuda* and *Tetraponera nigra* had exclusively arboreal nests. The nests of *Tapinoma melanocephalum* were sighted both in sandy ground and on the twigs of *Wedelia trilobata.*

The environmental variables, number of floral and ant species records significant variations between the zones (Tables 1, 2 and 3; Fig 5). The Shannon's diversity, Simpson's index of diversity and Shannon equitability values (alpha diversity indices) were calculated (Table 4). The dendrogram generated using Jaccard's classic and Bray–Curtis similarity coefficient values based on the number of shared species (Fig. 6) records the highest similarity between Zone IIA and Zone IIB at the level of 0.688 and 0.815 respectively.

Table 1: List of floral species found in the demarcated zones.

Plant species	Zone I	Zone IIA	Zone II B	Zone III	Zone IV	Zone V
Ipomea pes - capre	-	+	+	+	-	+
Canavalia rosea	-	+	+	+	-	-
Spinifex littoreus	-	+	+	+	-	-
Cuscuta chinensis	-	+	+	+	-	-
Derris scandens	-	+	+	-	-	+
Sesuvium portulacastrum	-	+	-	+	+	-
Wedelia trilobata	-	+	+	+	-	+
Scaevola taccada	-	+	+	+	-	+
*Casuarina equisetifolia**	-	+	+	+	-	-
Morinda citrifolia	-	-	-	+	+	+
Cassia tora	-	-	-	+	-	+
Clerodendrum inerme	-	-	-	+	-	+
Pongamia pinnata	-	-	-	+	-	-
*Acacia auriculiformis**	-	-	-	+	-	-
Thespesia populnea	-	-	-	+	-	-
*Pterocarpus sp.**	-	-	-	+	-	-
Cerbera odollum	-	-	-	-	-	+
Mimosa pudica	-	-	-	-	-	+
Leucas aspera	-	-	-	-	-	+
Tridax procumbens	-	-	-	-	-	+
*Cocos nucifera**	-	-	-	-	-	+
Avicennia officinalis	-	-	-	-	+	-
Sonneratia alba	-	-	-	-	+	-

* Planted flora in the study area.

Table 2: Check list of ant species recorded in the demarcated zones of the study area.

Subfamily	Species	Zone I	Zone IIA	Zone IIB	Zone III	Zone IV	Zone V
Formicinae	1. *Anoplolepis gracilipes* Smith, 1857	-	-	-	+[a]	-	-
	2. *Camponotus compressus* (Fabricius, 1787)	-	+	+	+	-	+[a]
	3.*Camponotus oblongus* (Smith, 1858)	-	-	+	-	-	+
	4.*Camponotus sericeus* (Fabricius, 1798)	-	-	-	-	-	+
	5.*Oecophylla smaragdina* (Fabricius, 1775)	-	-	-	+	-	+
	6.*Paratrechina longicornis* (Latreille, 1802)	-	+[a]	+[a]	+[a]	+	+
	7.*Nylanderia* sp.1	-	+[a]	+	+[a]	-	+[a]
	8.*Nylanderia* sp.2	-	-	-	+	-	-
	9.*Plagiolepis jerdonii* Forel, 1894	-	+[a]	+[a]	+[a]	-	+[a]
Myrmicinae	10.*Cardiocondyla nuda* (Mayr, 1866)	-	+[a]	-	+	-	-
	11.*Crematogaster subnuda* Mayr, 1879	-	+[b]	+	+[b]	+[b]	+[b]
	12.*Crematogaster* sp.1	-	-	-	+	-	-
	13.*Crematogaster* sp.2	-	-	-	-	-	+[a]
	14.*Meranoplus bicolor* (Guérin-Méneville, 1844)	-	-	-	-	-	+[a]
	15.*Monomorium floricola* (Jerdon, 1851)	-	-	+	-	-	-
	16.*Monomorium orientale* Mayr, 1879	-	+[a]	+	+[a]	-	+
	17.*Monomorium pharaonis* (Linnaeus, 1857)	-	+	+[a]	+	-	-
	18.*Monomorium* sp.1	-	+[a]	+[a]	+[a]	-	-
	19.*Pheidole* sp.1	-	+[a]	+[a]	+[a]	-	-
	20.*Solenopsis geminata* (Fabricius, 1804)	-	+[a]	+[a]	-	-	-
	21.*Solenopsis nitens* Bingham,1903	-	+	-	-	-	-
	22.*Tetramorium obesum* André, 1887	-	-	-	-	-	+[a]
	23.*Tetramorium smithi* Mayr, 1879	-	+	-	+[a]	-	+[a]
	24.*Tetramorium walshi* (Forel, 1890)	-	-	+[a]	+[a]	-	+
	25.*Tetramorium* sp. 1	-	-	-	+[a]	-	-
	26.*Tetramorium* sp. 2	-	-	-	+	-	-
Ponerinae	27.*Anochetus* sp.1	-	-	-	-	-	+
	28.*Anochetus* sp.2	-	-	-	+	-	-
	29.*Diacamma* sp.	-	-	-	-	-	+[a]
Dolichoderinae	30.*Tapinoma melanocephalum* (Fabricius, 1793)	-	+[a]	+[a]	+[b]	-	+
Pseudomyrmecinae	31.*Tetraponera nigra* (Jerdon, 1851)	-	-	-	-	+[b]	-
Total number of species		**0**	**14**	**13**	**20**	**3**	**15**
Number of arboreal nesting species		**0**	**1**	**0**	**2**	**2**	**1**
Number of ground nesting species		**0**	**9**	**8**	**10**	**0**	**8**

[a] Ground nest (Subterranian nest with or without prominent mound, beneath the wood, pebbles).
[b] Arboreal nest (constructed in or outside the stems or using leaves)

Table 3: The record of abiotic parameters (pH, salinity, $CaCO_3$, total organic matter, moisture content and air and soil temperature) and the correlation coefficient values between abiotic parameters and the number of plant and ant species in respective zones.

No. of ant species	No. of plant species	Soil Temperature (° C)	Air Temperature (°C)	pH	$CaCO_3$ (%)	Moisture Content (%)	Total organic Matter (%)	Salinity (ppt)	Zones
0	0	21.8 ± 1.04	27.25 ± 1.2	6.70 ± 0.3	4.25 ± 0.87	5.03 ± 0.9	0.63 ± 0.3	0.27 ± 0.12	Zone I
14	9	35.69 ± 6.2	32.65± 2.6	6.76 ± 0.21	5.61 ± 0.94	1.13 ± 0.3	2.1 ± 0.48	0.03 ± 0.01	Zone IIA
13	8	39.35±7.1	34.44± 2.4	6.70 ± 0.22	5.82 ± 1.21	0.04 ± 0.1	2.06 ± 0.29	0.06 ± 0.13	Zone IIB
20	15	39.55± 7.5	33.76±2.3	6.76 ± 0.19	4.72 ± 0.86	0.6 ± 0.2	2.19 ± 0.33	0.03 ± 0.02	Zone III
3	4	21.1± 0.35	34.4± 1.4	6.77 ± 0.09	2.1 ± 0.14	5.2 ± 0.6	2.28 ± 0.3	0.45 ± 0.21	Zone IV
15	12	31.63± 4.9	32.25± 3.4	6.75 ± 0.21	6.1 ± 1.7	1.33 ± 0.4	1.69 ±0.55	0.04 ± 0.03	Zone V
-	-	<0.0001	<0.0001	>0.05	<0.0001	<0.0001	<0.0001	<0.0001	P - value
Correlation coefficient values between abiotic parameters and the number of plant and ant species in respective zones									
-0.86	-0.75	-0.89	0.14	0.07	-0.92	0.94	-0.17	1	Salinity (ppt)
0.57	0.6	0.5	0.81	0.65	-0.07	-0.47	1		Total organic Matter (%)
-0.94	-0.85	-0.98	-0.21	-0.05	-0.81	1			Moisture Content (%)
0.64	0.52	0.72	-0.31	-0.31	1				CaCO3 (%)
0.33	0.47	0.01	0.23	1					pH
0.24	0.25	0.31	1						Air Temperature (°C)
0.91	0.8	1							Soil temperature (°C)
0.97	1								No. of plant species
1									No. of ant species

Abiotic parameter Values are mean ± SD

Discussion

Ants are terrestrial invertebrates frequently found in coastal or intertidal environment (Allen *et al.*, 2001a). The spit, a heterogeneous ecosystem demarcated into five zones in present study suggest significant variations between the zones based on vegetation complex and soil characteristics (Table 1; Figs. 5 and 7). A total of 31 species placed under 17 genera and 5 subfamilies recorded in present study (Table 2) suggest the presence of a rich and diverse ant fauna in Hejamadi Kodi spit, the coastal landform. The Myrmecinae ants dominated in all the zones (Fig. 2) and the zone wise distribution suggest the highest number of ant species in IIIrd zone (mixed vegetation) followed by the Vth (coconut plantation), IIA (creepy vegetation), IIB (creepy vegetation with moderate shrubs) and IVth zone (mangrove). The total absence of ant fauna in Ist zone may be attributed to the constant tidal influx and the total absence of any kind of vegetation. The selective distribution of *Paratrechina longicornis* and *Crematogaster subnuda* in zones IInd, IIIrd, IVth and Vth ; whereas *Anochetus* sp. 1, *Camponotus sericeus*, *Camponotus oblongus*, *Crematogaster* sp. 2, *Diacamma* sp. *Meranoplus bicolor* and *Tetramorium obesum* only in zone Vth; *Anoplolepis gracilipes*, *Crematogaster* sp. 1, *Nylanderia* sp. 2, *Oecophylla smaragdina*, *Tetramorium* sp. 1 and *Tetramorium* sp. 2 only in zone IIIrd; and *Tetraponera nigra* only in zone IVth suggest association/dependence of ant species on specific host plants and the associated fauna for food and shelter. Earlier reports too have also documented that vegetation kind/pattern influences the richness and distribution of ant species (Kusnezov, 1957; Boomsma and Van Loon, 1982b; Gadagkar *et al.*, 1993; Bonte *et al.*, 2003; Palomo *et al.*, 2003; Cardoso *et al.*, 2010).

In addition the percent level of $CaCO_3$, total organic matter, moisture content, temperature of air and soil, pH and salinity (Table 3) recorded in the present study points that in particular $CaCO_3$ and temperature of the soil play a significant role probably contributing to the varied distribution of ant species, thereby conferring ability to survive in otherwise harsh environment (Boomsma and Isaaks, 1982a) which suggest varied toleration range for different ant species to environmental variables (Holldobler and Wilson, 1990) permitting temporal resources partitioning (Orivel and Dejean, 2001). The pattern of distribution of ground nest probably relates to the availability of food resources and vegetation complexity (Table 1 and 2; Fig. 8) which in turn probably plays an important role in soil turnover and the nutrient recycling (Lal, 1988). Some species of ants occupied the nest constructed by other organisms (Fig. 4). Whereas the *Crematogaster subnuda* (zone IIA, IIIrd, IVth and V) and *Tetraponera nigra* (zone IVth with mangrove) had exclusively arboreal nests suggesting that the tidal influx probably limits the activity of ants to the crown of the trees (Lopes and Aguiar dos Santos, 1996; De Baar and Hockey, 1993). The nests of *Tapinoma melanocephalum* were sighted both in sandy ground as well as on twigs of *Wedelia trilobata* suggesting that *Tapinoma melanocephalum* is comparatively highly adapted to environmental variables (Andersen, 1990).

Shannon index and Simpson's diveristy index, the measures of alpha diversity suggest that the zone Vth is more diverse followed by III, IIB and IIA (Table 4). The computed evenness values (Shannon

equitability) suggest that the distribution of ant species is more even in zone Vth followed by IIB, III and IIA. The dendrogram obtained using Jaccard's classic and Bray–Curtis similarity coefficient values (beta diversity indices) indicates highest similarity between Zone IIA and Zone IIB at the level of 0.688 and 0.815 respectively (Fig. 6). More or less similar species richness shared between zone IIA, IIB and IIIrd probably relates to more or less the similar vegetation type in these zones (Table 1).

The diversity and distribution pattern of ant species observed in demarcated zones in present study points to the selective needs (in terms of food and shelter) and adaptive capabilities of ant species to harsh prevailing conditions (Andersen, 1990) compared to inlands particularly with reference to the soil temperature, $CaCO_3$ and the type of plant species found in specialized habitats of the sand spit permitting selective association between flora and fauna and thus contributing to their successful survival and reproductive fitness in the harsh conditions met in on coastal habitats.

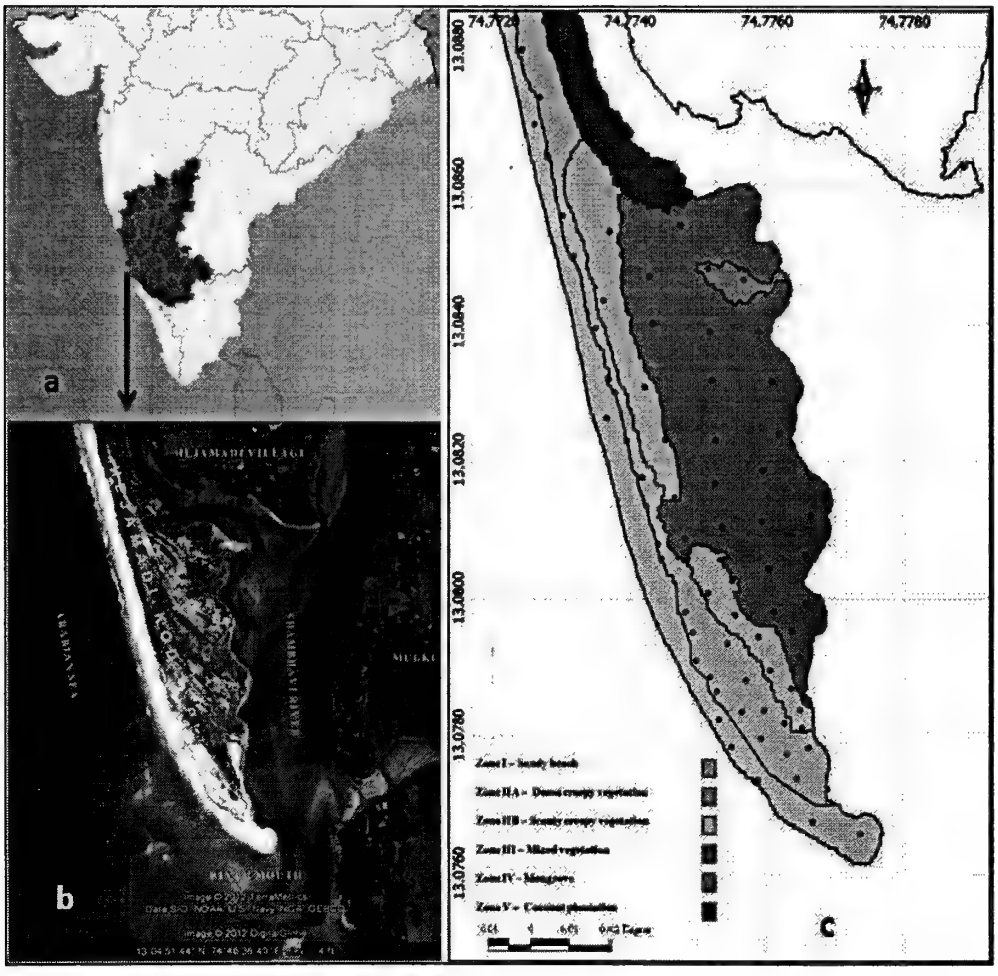


Fig. 1: A map showing a) location of Udupi district b) Google image of Hejamdi Kodi spit and c) demarcated zones and sampling points (•).

Table 4: Diversity indices for demarcated zones in the study area.

Zones	No.of species	Shannon[a] (H')	Simpson index[b] (1-D)	Shannon equitability [c](J)
Zone IIA	14	2.098	0.8471	0.7949
Zone IIB	13	2.189	0.8613	0.8536
Zone III	20	2.402	0.8689	0.8018
Zone IV	3	**	**	**
Zone V	15	2.588	0.918	0.9556

[a] The values ranges between 1.5-3.5 and values nearing 1.5 is considered to be less diverse.
[b] The values ranges between 0-1 and values nearing 0 is considered to be less diverse.
[c] The values ranges between 0-1 and values nearing 0 is considered to be more uneven.
** Not computed due to small sample size.

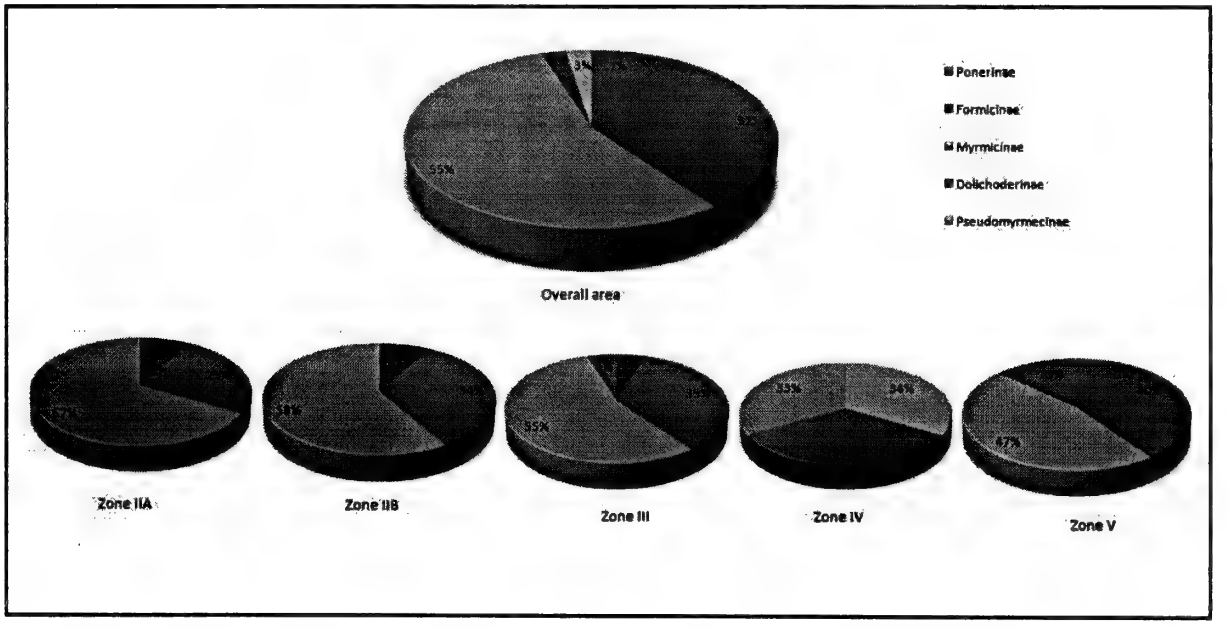
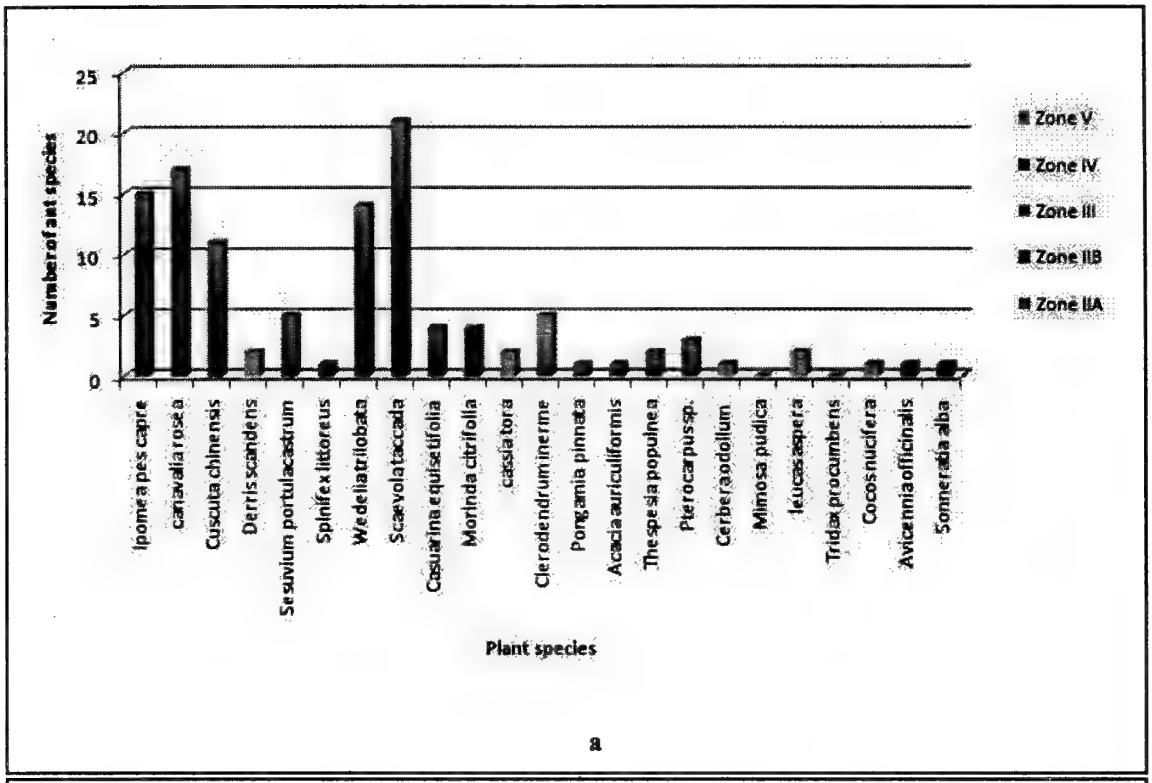


Fig. 2: Percent occurrence of subfamilies in the study area.



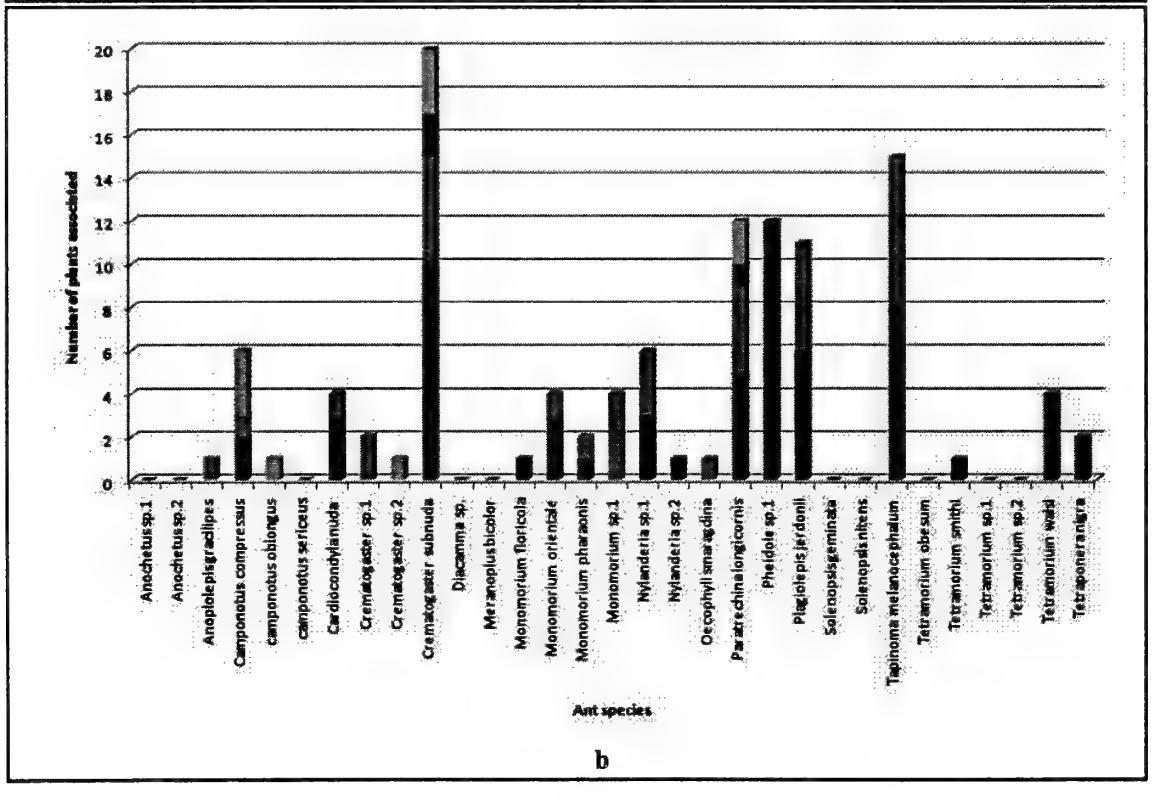


Fig. 3: The association between a) number of ant species with plants b) ant species with number of plants in the demarcated zones.

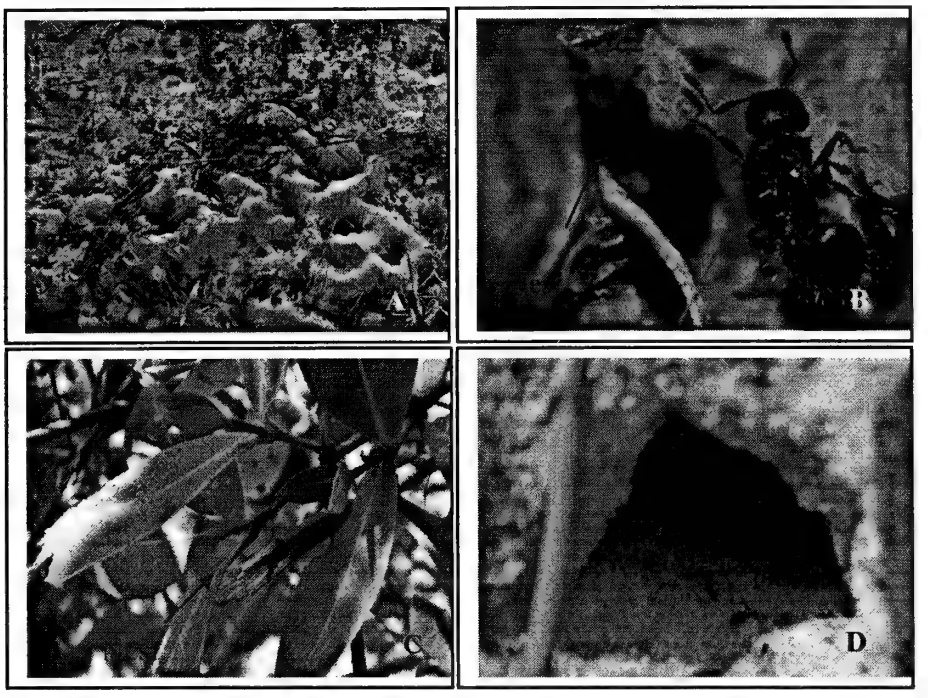


Fig. 4: Nest of (A) *Pheidole* sp., (B) *Crematogaster* sp., (C) *Tetraponera nigra* and (D) *Paratrechina longicornis* using the holes made by crabs.

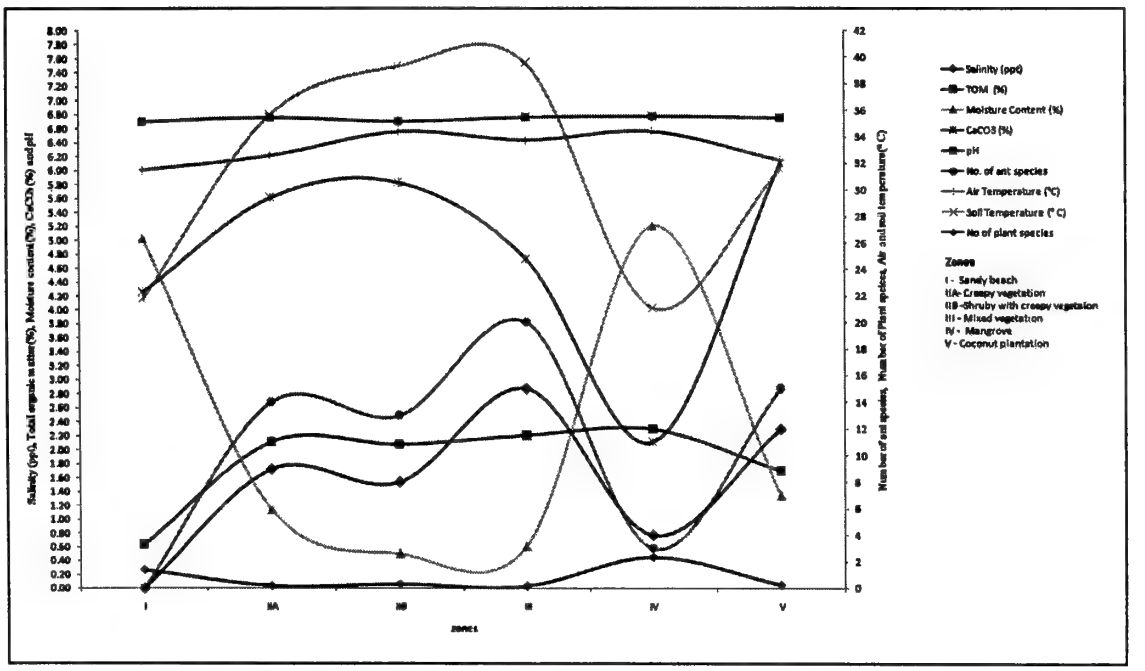


Fig. 5: The correlation between abiotic parameters (pH, salinity, $CaCO_3$, total organic matter, moisture content and air and soil temperature) and number of plant and ant species in respective zones.

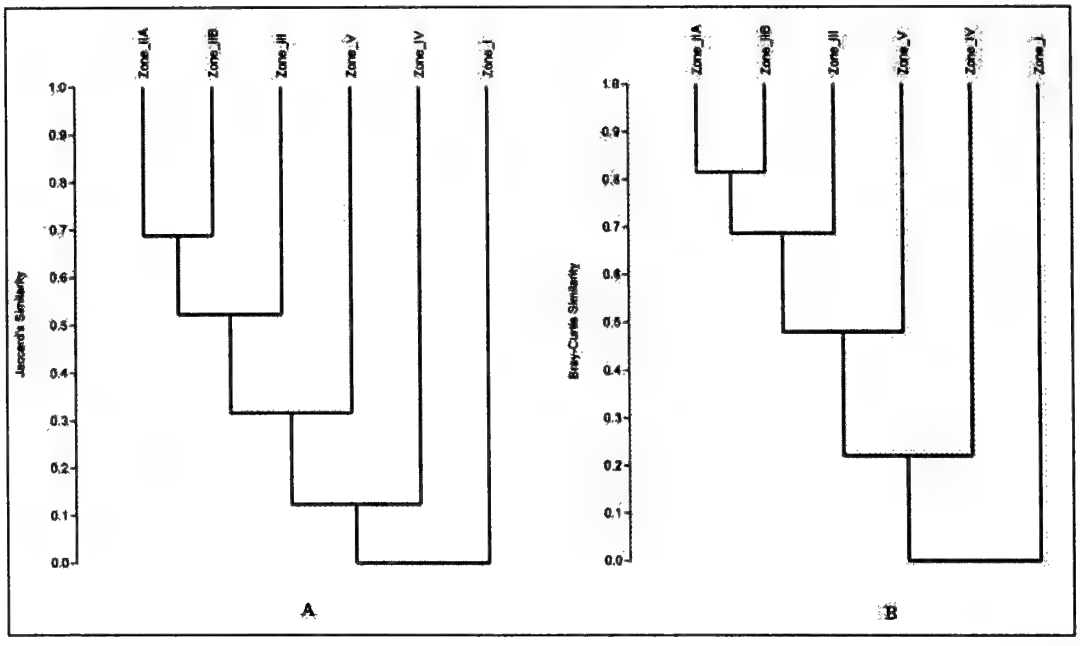


Fig. 6: Dendrogram generated using (A) Jaccard's similarity and (B) Bray-Curtis similarity coefficient values based on the number of shared species between the habitats.

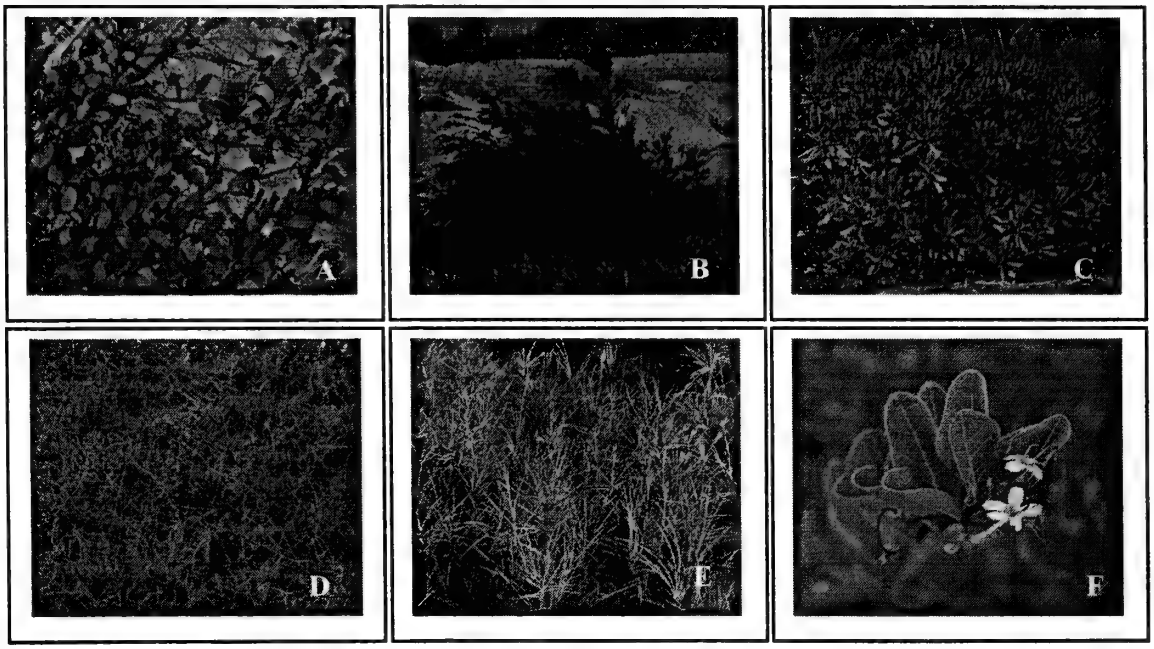


Fig. 7: Figures of some common plant species in the study area. A. *Ipomea pes - capre*, B. *Casuarina equisetifolia*, C. *Scaevola taccada*, D.*Cuscuta chinensis*, E. *Spinifex littoreus*, D. *Clerodendrum inerme*.

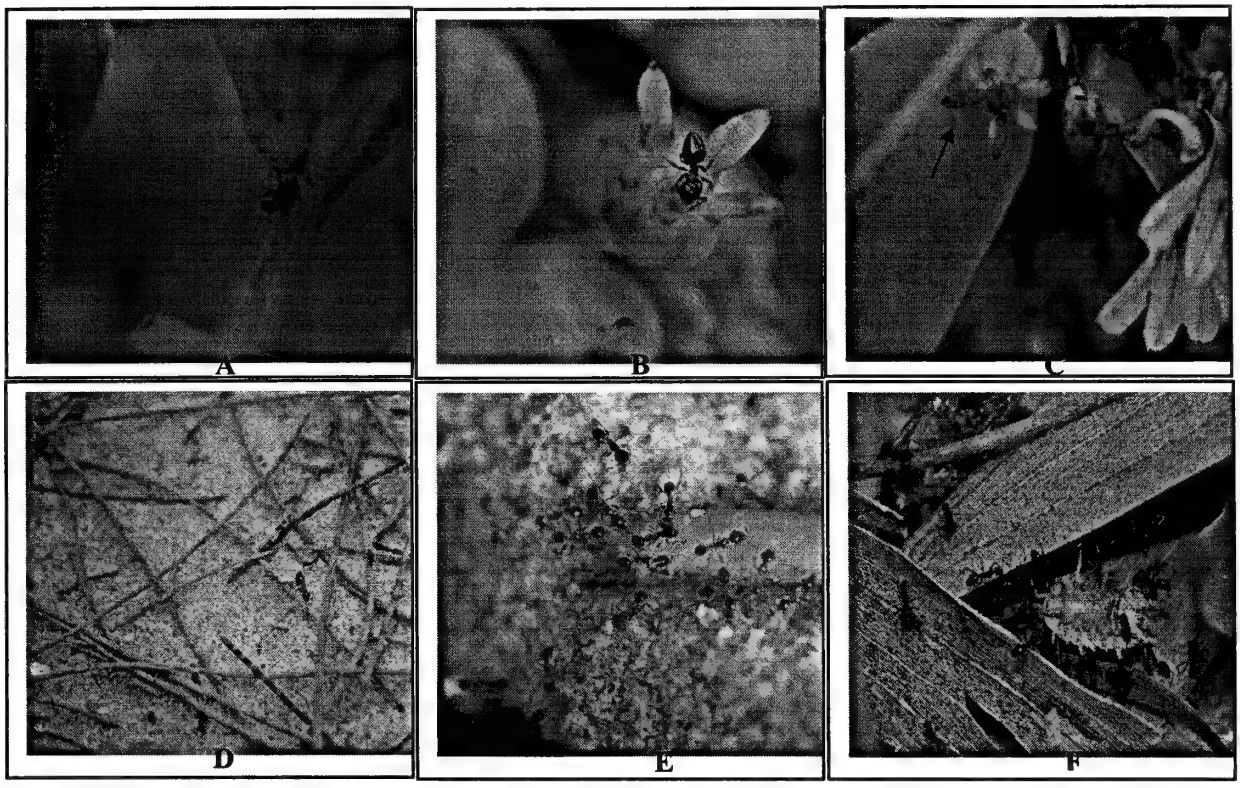


Fig. 8: Foraging ants in search of food – (A) The *Pheidole* sp. seen at the base of *Ipomea pes - capre* for extrafloral nectaries; (B) *Crematogaster* sp. and (C) *Paratrechina longicornis* reaching the fruit of *Scaevola taccada* for extrafloral nectaries; (D) *Pheidole* sp. carrying a crustacean and (E) the bait (fried item) material; (F) *Paratrechina longicornis* carrying a crustacean.

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First record of the Srilankan Processional Termite, *Hospitalitermes monoceros* (Konig) (Termitidae: Nasutitermitinae) from India

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Abstract

***Hospitalitermes monoceros* (Konig), a termite species hitherto endemic to Sri Lanka, is reported for the first time from India collected in Chinnar Wildlife Sanctuary, Kerala. Since the original description is scanty, the species is redescribed and illustrated based on soldier and worker castes.**

Keywords: *Hospitaliteremes monoceros, termite, Redescription, India, Sri Lanka.*

Introduction

The genus *Hospitalitermes* Holmgren, 1912 (Termitidae: Nasutitermitinae) is distributed from Sri Lanka and India, throughout Southeast Asia, Southern China and across Indonesia archipelago to New Guinea (Jones, 2012). They are among the few unique termites, foraging in columns in open air during late evenings for epiphytes like lichens, blue green algae growing on the surface of tree trunks, in canopies of tropical forests (Collins, 1979). So far under the genus three species *H. madrasi* (Snyder, 1934), *H. jepsoni* (Snyder, 1934), *H. blairi* Roonwal and Sen-Sarma, 1956 have been reported from India (Chhotani, 1997).

As a part of our taxonomic investigations on Termites of Kerala, we report *H. monoceros* (Konig, 1779), for the first time from India hitherto reported from Sri Lanka alone. The genus *Hospitalitermes* is also reported here for the first time from Kerala, and is diagnosed by a combination of characters in the soldier caste: head with a constriction behind antenna, mandibles with a pointed spine-like process, antenna with 14 segments, hind legs extending beyond abdomen with an elongate tibia (Chhotani, 1997 and Somnuwat *et al.,* 2004). The observed absence of the cockroach notch on the molar plate of the right mandible (Fig. 4) in the worker caste categorically differentiates them from the closely related genus *Lacessititermes* Holmgren, 1912 (Syaukani *et al.,* 2011). Inhabiting in evergreen and semievergreen forests, these are open air foragers distributed in Oriental and Papuan Region. The original description of *H. monoceros* being scanty, both the soldier and worker castes of the species are redescribed here.

Material and Methods

Specimens were collected from five colonies while foraging at Chinnar Wildlife Sanctuary (10°05' to 77°22' N latitude and 77°05'to 77°17'E longitude), located in the rain shadow region of the Western Ghats, Idukki, Kerala, India. The specimens were preserved in 80% alcohol. Dissections and measurements were also made in 80% alcohol under the stereo zoom microscope, Leica M205A, at magnifications between 10-160X. Mandibles of the worker caste were mounted on glass slides in Canada balsam and then

examined for diagnostic characters. Photographs were taken using a Leica DFC 500 camera, and processed with the help of extended focus software, LAS version 3.6.

The identification was made using Chhotani (1997) and Somnuwat *et al.* (2004). Morphological terminology for describing soldiers and workers follow Tho (1992), Sands (1998) and Gathorne-Hardy (2001), while measurements are taken in accordance with Chhotani (1997). Studies on worker mandibles follow Fontes (1987).

All specimens are deposited in the National Zoological Collections of the Zoological Survey of India (ZSI), at Calicut (Kozhikode), Kerala, India.

Taxonomy

***Hospitalitermes monoceros* (Konig, 1779)**

Syn: ***Termes monoceros atrum*** Konig, 1779: 28, pl. 1: figs. 10–11 [first introduced as *Termes monoceros atrum* Konig, 1779.

Type locality- Sri Lanka (Ceylon).

— Ahmad, 1958: 139, 141.

— Prashad and Sen-Sarma, 1960: 26–32.

Redescription

Soldier (Figs. 1-2)

Monomorphic; varying in size; head capsule pale brown anteriorly and blackish brown posteriorly; antennae dark brown; nasus pale brown; pronotum, abdominal tergites, coxal and femoral regions of legs in dorsal view slightly paler than head capsule; thorax with a fine, whitish line medially; sternites and other part of legs brownish white.

Head capsule in dorsal view strongly constricted behind antennal sockets, with anterior part excluding nasus extremely smaller than posterior part, dorsal outline including nasus in profile concave or appearing depressed; nasus in dorsal view relatively short, less than half as long as head capsule, hairy at tip of nasus, in profile slightly up curved, but apical third feebly down-curved; eyes small whitish spots; antennae elongate with 14 segments, third segment twice as long as second (0.21 : 0.1 mm), fourth shorter than third, fourth and fifth nearly equal in length, seventh to fourteenth gradually decreasing in length; head capsule pyriform with two long hairs on posterior part of head capsule; mandible vestigial, each with long brown, pointed spine-like process.

Body wall strongly sclerotized, gut not clearly visible; pronotum saddle shaped, almost half as long as wide, anterior margin weakly convex and feebly indented in the middle, posterior margin strongly convex without notch; tergites thinly hairy with short hairs, sternites moderately hairy.

Legs moderately long, hairy, hind tibia elongate (2.14-2.55 mm), tibial spurs 2:2:2; tarsi four-segmented; cerci two segmented.

Table 1: Measurements of soldiers of *H. monoceros* (n=10)

Characters	Measurements (mm)
Head length including nasus (HLN)	1.71-1.81
Head length measured to base of mandible (HL)	1.16-1.29
Nasus length (NL)	0.45-0.60
Nasus index (NL/HL)	0.39-0.52
Maximum head width (HW)	1.16-1.21
Width at constriction (CW)	0.78-0.80
Head constriction index (CW/HW)	0.65-0.69
Head bulge (HB)	0.40-0.54
Head bulge index (HB/HL)	0.33-0.42
Pronotum length	0.35-0.43
Pronotum width	0.63-0.66
Total body length	3.97-4.43
Length of hind tibia	2.14-2.55

Worker (Figs. 3-5)

Dimorphic; *Major Worker*: head capsule subquadrate (length to base of mandibles 1.16-1.19 mm, maximum width 1.33 mm), dark brown to black, epicranial suture prominent, fontanelle plate longish white; labrum slightly pale brown; post clypeus swollen dark brown length less than half of width; antennae brown with 15 segments, segment three much longer than two (1.58: 1.21 mm); segment four (1.41 mm) slightly longer than segment two. Head and body covered with very minute hairs, few dorsally, but numerous ventrally.

Thorax brown, pronotum strongly saddle shaped, anterior margin weakly convex and feebly indented in the middle, posterior margin strongly convex without notch and deeply notched antereo-laterally; abdominal tergites pale brown, femora dark brown and beyond tibia brownish white.

Minor Worker (Fig. 3): similar to major worker except being small in size; third antennal segment as long as segment two and pronotum not deeply notched antereo-laterally.

Mandibles (Fig. 4): apical tooth of left mandible shorter than first marginal; second marginal tooth absent; third marginal tooth smaller than first and fairly protruding from cutting edge, separated from molar prominence by a distinct gap; apical tooth of right mandible shorter than first marginal tooth; first marginal tooth with anterior edge almost straight; second marginal tooth clearly recognized and separated from much larger first marginal tooth; posterior edge of second marginal tooth nearly straight; strongly developed molar ridge of mandible (Fig. 5) aids in scraping and grinding wood; cockroach notch absent in molar plate of right mandible.

Alate: unknown

Material examined: 10 soldiers and 10 workers, 2.viii.2012 (coll. C. Bijoy); collected randomly from 5 colonies (Champakkad: Chinnar Wild life Sanctuary, Idukki, Kerala). Numerous samples of both soldiers and workers collected from 5 different colonies within 4km radius of Champakkad have been preserved in 80% ethanol (Colony code: ZSI/WGRC/IR/INV/3079-3083) deposited at Zoological Survey of India, Western Ghat Regional Centre, Calicut (Kozhikode), Kerala, India.

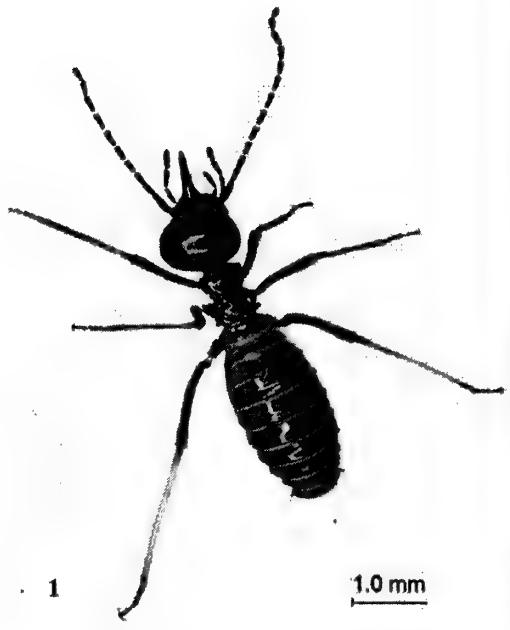

Fig. 1: *H. monoceros*, soldier (dorsal view).

Discussion

H. monoceros resembles most to *H. madrasi* Snyder. The soldiers of both species are dark with pale rostrum and numbers of their antennal segments remain the same. In both the species the worker caste is dimorphic. To mention the differences between the species, *H. monoceros* has a blackish brown head with paler anterior part and the third segment of antennae is twice as long as second segment, while in *H. madrasi*, head colour is castaneous brown to dark reddish brown and the third segment of antennae is 2.2-2.5 times as long as second. Further *H. madrasi* is a larger species with body size 5-5.30 mm than that of *H. monoceros* (3.97-4.7 mm).

The finding of a species, hitherto considered endemic to Sri Lanka, in south Kerala is not surprising as Amina and Rajmohana (2013) also very recently reported *Ceylonitermelles* Emerson, 1960, a Srilankan endemic genus again from South Kerala signifying occurrence of Sri Lankan termite taxa in Southern India.

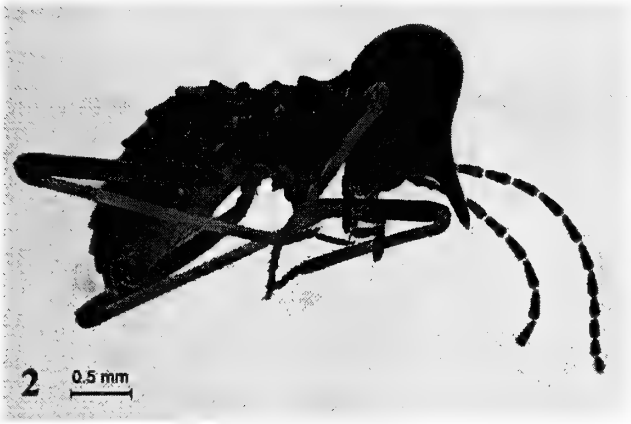

Fig. 2: *H. monoceros*, soldier (lateral view).

Fig. 4: *H. monoceros*, mandible of worker.

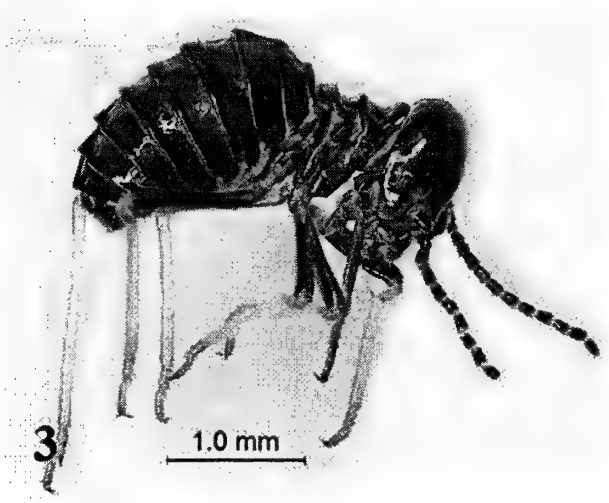

Fig. 3: *H. monoceros*, minor worker (lateral view).

Fig. 5: *H. monoceros*, molar ridges on right mandible of worker caste.

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Status of the Genus *Spalgis* Moore with taxonomic notes on the type species, *Spalgis epeus* (Westwood) in the Indian Himalaya

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Abstract

As per the earlier records, genus *Spalgis* Moore is represented by two species *viz., epeus* Westwood and *baiongus* Cantlie and Norman in India, the latter one being very rare and restricted to Assam. During the repeated surveys undertaken in an ICAR, New Delhi sponsored project, only the type-species of this genus, *Spalgis epeus* (Westwood) has been reported from the Himalayan region in India. The diagnosis of the genus has been updated by inclusion of the characters of the male and the female genitalia. The survey work shows that the species is quite rare in the Himalaya.

Keywords: *Himalaya, male genitalia, female gentalia, Lycaenidae, Spalgis.*

Introduction

From the Indian region, about 1438 species of butterflies have been documented and out of these, more than 438 species belong to the family Lycaenidae which makes about 30% of this total butterfly diversity (Evans, 1932; Wynter-Blyth, 1957; Haribal, 1992; Khoshoo, 1994 and Kehimkar, 2008). Owing to small size, less attractive colouration and difficulty in identification, the butterflies of family Lycaenidae have not been adequately explored and more so the taxonomic account of different taxa warrants updating. The genus *Spalgis* Moore, is represented by eight species *viz., epeus* Westwood, *baiongus* Cantlie and Norman, *takanamii* Eliot, *asmus* Parsons, *jacksoni* Stempffer, *lemolea* Druce, *pilos* Druce and *tintinga* Boisduval in the Oriental and the African regions (d' Abrera, 1986; Bridges, 1988 and Eliot, 1992). Out of these, the former two species have been reported from India and according to Cantlie and Norman (1960) and Cantlie (1963), the species, *baiongus* restricted to Assam is very rare one. Further, d' Abrera (loc. cit.), who advocated the taxonomic revision of the other species i.e., *epeus* Westwood has reported eight subspecies viz., *e. epeus* Westwood (India, Ceylon to Peninsular Malaya, Nicobars, Mergui islands), *e. nubilus* Moore (Andamans, Pulau Tiomam), *e. flangola* Kheil (Borneo, Sumatra, Nias), *e. titius* Fruhstorfer (Java, Bali, Lombok, Sumba, Sumbawa), *e. substrigata* Snellen (Sulawesi), *e. strigatus* Semper (Southern and Central Philippines, Palawan), *e. semperi* Fruhstorfer (Northern Philippines and Luzon) and *e. dilama* Moore (Taiwan) under it from the respective localities / areas from the Oriental region.

Observations

Genus *Spalgis* Moore

Common name: The Apefly

Moore, 1879, Proc. zool. Soc. Lond.: 137; de Nicéville, 1890, Butts India Burmah Ceylon **3**: 54; Evans, 1932, Ident. Indian Butts (2nd 3d.): 213; Cantlie and Norman, 1960, J. Bombay nat. Hist. Soc. **57** (2): 424; Cantlie, 1963, Lyc. Butts Revised: 29.

Type-species: *Gerydus epeus* (Westwood) Westwood, [1851], In Gen. diurn. Lep. (2): 502.

Generic diagnosis: eyes smooth; labial palpi porrect, second segment laterally compressed, third segment acuminate; antenna shorter than half the length of forewing, gradually thickening to slender club, nudum extends deep into flagellum; each leg with tibia shorter than femur, the latter hairy, terminal tibial spurs absent; forewing with 11 veins, stalk of veins R_3+R_5 separated very briefly before end cell; male genitalia with an undivided hood-like uncus, brachia sharply curved, tapering into acute apices, vinculum moderaely wide, saccus obsolete, each valva large, bottle-shaped laterally, aedeagus moderate, slender, subzone longer than suprazone, ductus ejaculatorius enters dorsad, coecum elongated, rounded; female genitalia with genital plate not developed, ductus seminalis enters dorsad at base of ductus bursae, corpus bursae shorter, egg-shaped, a pair of spicule shaped signa present, apophyses anteriores small, apophyses posteriores moderately long, papilla analis sparsely pilose.

***Spalgis epeus* (Westwood)**

Common name: The Apefly

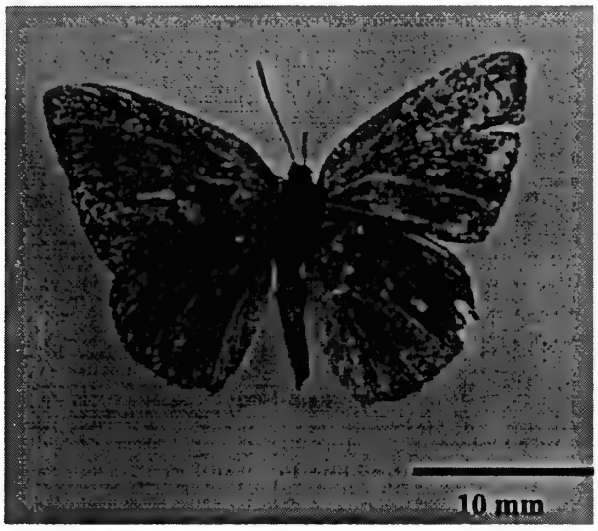
Westwood, [1851], In Gen. Diurn. Lep. **2**: 502 (*Gerydus*); Moore, 1879, Proc. Zool. Soc. Lond.: 137 (*Spalgis*); de Nicéville, 1890, Butts India Burmah Ceylon **3**: 55 (*Spalgis*); Cantlie, 1963, Lyc. Butts Revised: 30 (*Spalgis*).

***Spalgis epeus epeus* (Westwood)**

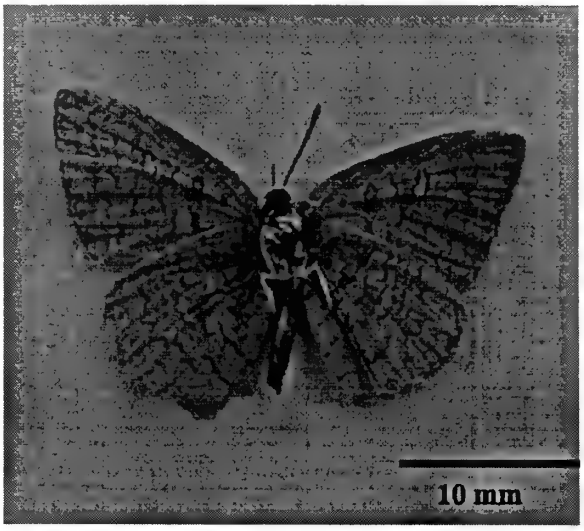
Westwood, [1851], Gen. Diurn. Lep. **2**: 502 (*Gerydus*).

Male genitalia: Symmetrical, relatively much smaller sized, well sclerotized; uncus undivided, with apex rounded, each lateral portion broad, rectangular, pilose; brachia short, laterally compressed, hook-shaped, gradually tapering to acute apices; subscaphium not developed; tegumen broad, triangular band shaped; lateral windows deep; vinculum long and narrow, with upper portion produced to oval lateral flaps behind tegumen; saccus obsolete; each valva large, bottle-shaped laterally, costae of both sides joined by a median semimembranous ridge, sacculus broad, band-shaped, apical portion of each sharply divided into teeth like halves, pilose; juxta unique, comprising two curved attenuate processes extending well beyond valvae; aedeagus moderate, straight, slender, with subzone longer than suprazone, apex narrower and ventrally produced, vesica inconspicuous, subzone with an oblique short opening for bulbus ejaculatorius, the latter siphon-shaped, ductus ejaculatorius enters dorsad, coecum elongated, with laterally compressed rounded apex.

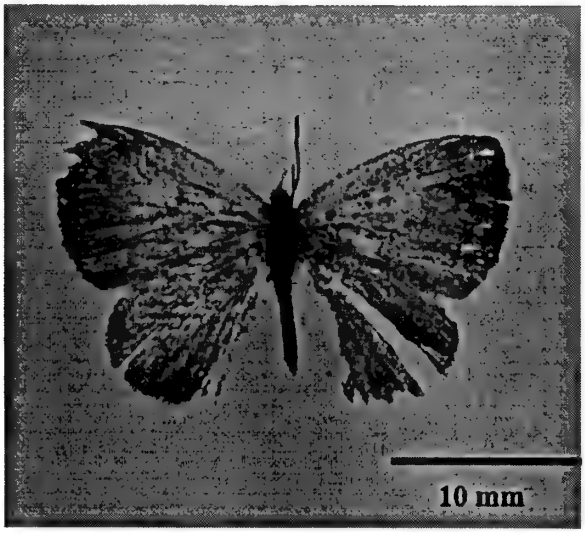
Female genitalia: Lodix rectangular with small moderately sclerotized patches at posterior angles, otherwise membranous; genital plate not developed; ductus seminalis enters on dorsal side at base of



(Male, dorsal view)

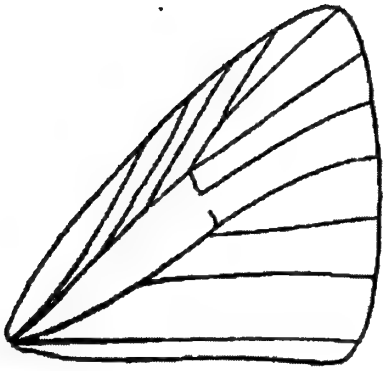


(Male, ventral view)

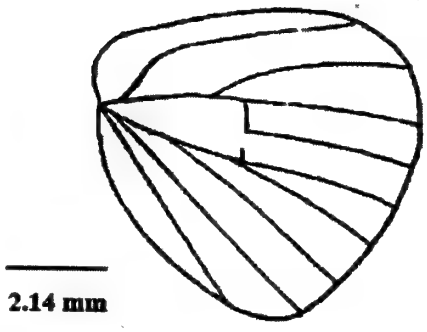


(Female, dorsal view)

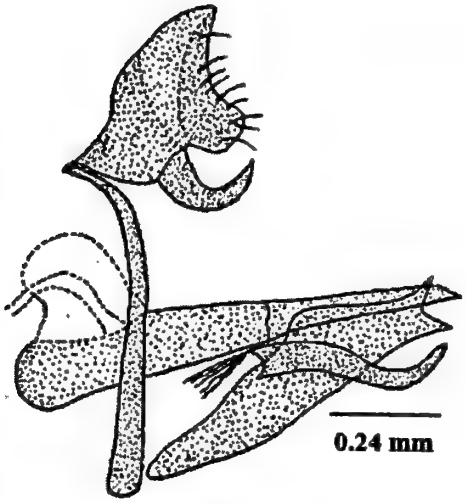
***Spalgis epeus epeus* (Westwood)**



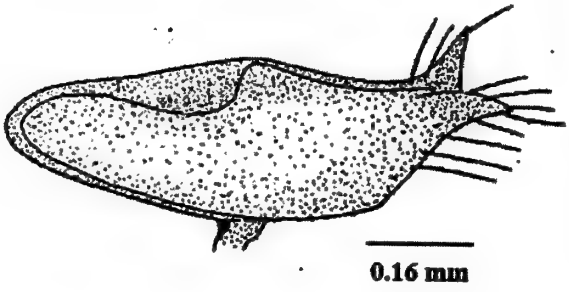
Venation of forewing



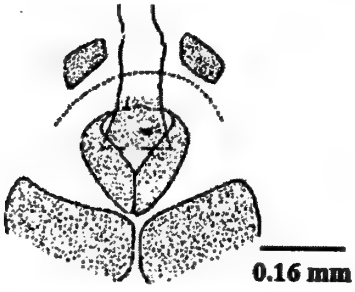
Venation of hindwing



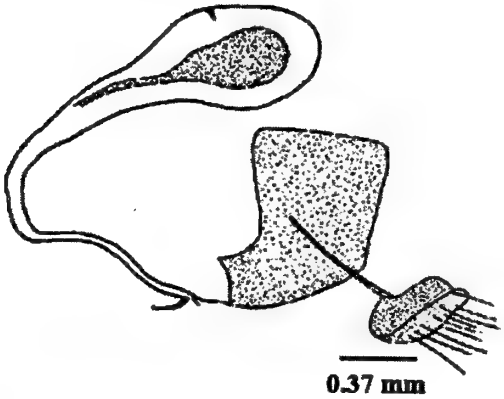
Male genitalia (lateral view)



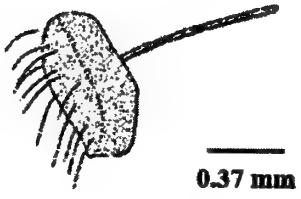
Left valva (inner view)



Area of 8th sternum



Female genitalia (lateral view)



Papilla analis

Spalgis epeus epeus (Westwood)

ductus bursae; the latter opens in funnel shaped semimembranous pouch at base, gradually broadens and goes imperceptibly into corpus bursae; corpus bursae egg-shaped, membranous, shorter than ductus bursae, a pair small spicule-shaped signa present in middle; proximal margin of 8th tergum deeply excavated laterally; apophyses posteriores moderate, laterally compressed, almost straight structures, papilla analis suboval, with basal half sclerotized, distal half quite membranous, sparsely pilose.

Forewing length: Male, 11 mm; Female, 12 mm.

Material examined: Assam: 1 ♀, 14.V.95, Bashistha, 250 m ASL, Kamrup. West Bangal: 1 ♂, 19.V.95, Sivoke, 270 m ASL, Darjeeling.

Range: 250-270 m ASL.

Old distribution: Ceylon, South India to Bengal, Kumaon to Burma, Nicobars.

Larval food: Carnivorous on scale insects and mealy bugs (Coccidae) (Sevastopulo, 1973).

Remarks

During the course of surveys in the Hamalaya, one male and one female of this type-species, collected from above mentioned localities have been identified from the relevant literature sources (de Nicéville, 1890; Bingham, 1907; Evans, 1932; Peile, 1937; Wynter-Blyth, 1957; Cantlie, 1963 and d' Abrera, 1986). The material has also been compared with the reference collections lying at I.A.R.I., New Delhi. The male genitalia of the species agrees with an account of the same given by Stempffer (1957) and Eliot (1992). However, the description of various constituent parts of the male genitalia need elaboration. Besides doing so, an account of the female genitalia is also furnished for the first time. Further, the species, under reference, is the type-species of the genus *Spalgis*, proposed by Moore (1879) on apparently superficial characters such as wing shape and presence of vein R_3. Accordingly, the diagnosis of the said genus has been updated by inclusion of the characters of the male and the female genitalia. It may also be pointed out that except for Cantlie (loc. cit.) and Bridges (1988), workers like Moore (loc. cit.), de Nicéville (loc. cit.), Bingham (loc. cit.), Evans (loc. cit.), Peile (loc. cit.), Wynter-Blyth (loc. cit.), Stempffer (loc. cit.), d' Abrera (loc. cit.), Seki *et al.* (1991) and Eliot (loc. cit.) have spelled the species as *epius* Westwood rather than *epeus* Westwood. The present survey work shows that the species is quite rare and is represented by its nominotype in India.

Acknowledgemnts

The author is grateful to Dr. H.S. Rose, the Principal Investigator of ICAR, New Delhi sponsored project on butterfly diversity of Himalaya (1995-1998) for much needed expertise and literature.

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Quantitative changes in lipids and carbohydrates of temporal workers and drones in *Apis cerana indica* (Fabricius)

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Abstract

Lipids and sugars from temporal castes of *Apis cerana indica* (Fabricius) were analysed qualitatively and quantitatively. Cholesterol, free fatty acids, triglycerides, methyl esters and cholesterol esters were higher in nurse and food storer but decreased in middle-aged and forager bees. The haemolymph, glucose and fructose showed significant increase in bees performing extranidal tasks while trehalose level was found to be high only in intranidal tasks. Glycogen content from thorax and abdomen was more in nurse and food storer workers but substantially decreased in guards and foragers.

Keywords: *Apis cerana indica*, lipids, sugars, worker castes, drones.

Introduction

Honeybee workers exhibit temporal division of labour. With age they shift their task from cell cleaning, comb building, food processing to outside tasks like guarding and foraging (Winston, 1987 and Johnson, 2008). This age related temporal division of labour within the worker caste in honeybees are elicited by physiological changes (Robinson, 2009). The onset of foraging for instance in honeybees are associated with decrease in abdominal lipids (Toth and Robinson, 2005), and increase in thoracic glycogen store (Harison, 1986). In *Apis mellifera*, foragers have been found to contain fewer lipids than the nurse bees (Toth and Robinson, 2005), further foragers reverting to nursing are not able to perform their task efficiently as nurse bees due to their low level of lipids. These studies showed that differences in lipids are closely related to switching of tasks in bees (Toth and Robinson, 2005).

Level of sugars in the form of trehalose, glucose and fructose in the honeybee *Apis mellifera* have been reported to vary widely (Bounias and Morgan, 1984; Bozic and Woodring, 1997; Abou-Seif *et al.*, 1993; Fell, 1990 and Leta *et al.*, 1996). This variability in haemolymph sugar composition is influenced by many factors including differences in diet (Crailsheim, 1988; Abou-Seif *et al.*, 1993 and Woodring *et al.*, 1993), metabolic rate (Moffatt, 2000 and Blatt and Roces, 2001), physiological changes and environmental conditions (Kunert and Crailsheim, 1988).

Most of these studies are based on Western honeybee, *Apis mellifera* (Winston, 1987; Seeley, 1995; Robinson, 1992 and Robinson *et al.*, 1994). However studies in the Asian bee, *Apis cerana indica* (Fabricius) is lacking, therefore the present study was carried out to determine the composition and changes in the profile of various sugars and lipids among age related temporal worker castes in the bee *Apis cerana indica*.

Materials and Methods

Colony of *Apis cerana indica* was reared in a wooden hive box. Task specific bees (n=20 bees per pool) were collected from the colony and immediately cold immobilized.

Lipid extraction and analysis: Wings and legs were removed from the thorax of each bee. Task specific bees were pooled and homogenized in a glass tissue grinder by adding chloroform/methanol/water for extraction of total lipids following the protocol of Bligh and Dyer (1959).

Separation of Lipids by Thin-layer chromatography (TLC) analysis: Various lipid classes of the lipid extract were separated by TLC on 20 x 20 cm glass plates coated with silica gel GF of thickness 0.25 mm. Plates were activated by heating in an oven at 110°C followed by cooling. Plates were run with petroleum ether (b.p. 60-70°C)/diethyl ether/acetic acid (90:10:1; v/v/v) as mobile phase according to the procedure of Mangold (1961 and 1964) and Malins and Mangold (1960). The TLC chamber was equilibrated with the mobile phase for 15 minutes before introducing the spotted plate. After running, the plates were dried with a stream of air and were visualized in iodine chamber. Bands were identified by comparing their relative mobility to authentic standards. For each detected band, the gel was scraped off into 20 ml test tubes and used for quantitative estimation of lipids.

Neutral lipids were quantified spectrophotometrically using the method of Amenta (1964). Phospholipids were determined according to the procedure of Raheja *et al.* (1973). Standards were purchased from Sigma, USA and were 99% pure. All solvents used were of HPLC grade. Data was expressed as mg of lipids/bee.

Sugar analysis: Haemolymph from the above mentioned task groups were collected by puncturing the dorsal neck membrane with microcapillary tube after ventrally deflecting the head. The collected haemolymph was immediately expelled into chilled eppendorf tube containing 4.5 ml of 80% ethanol to precipitate proteins. The sample was centrifuged at 1200 rpm for 10 minutes. The supernatant obtained was used for qualitative and quantitative analysis of sugars.

Separation and detection of sugars by TLC: Sugar standards were purchased from Merck (Darmstadt, Germany) and dissolved in 80% ethanol. TLC was performed on 5 x 20 cm glass plates coated with silica gel GF of thickness 0.25 mm. Activation and equilibration of plates were done as mentioned above. Standards and samples were applied on the TLC plates and were run to a distance of 15 cm with dimethyl formamide / n-butanol / water (3:12:2) as the mobile phase. Plates were then dried with a stream of air. Sugars were visualized in iodine chamber. Spots on plate were identified with the reference sugars run parallel.

Total soluble sugar, trehalose and fructose were determined according to the method of Arslan *et al.* (1986).

For determination of glucose, 30µl of extracted haemolymph were mixed with equal volume of water and added to 540 µl of 3% Trichloroacetic acid and analyzed by O-toluidine following the protocol of Dubowski (1962). Data was expressed as µg of sugars/µl of haemolymph.

Quantification of Glycogen in thorax and abdomen of workers and drones: Four groups of workers based on specific tasks (nurse, food storer, guard, and forager bees) and drones of unknown-age were used for analysis of glycogen separately for thorax and abdomen. Nurse bees were obtained with their head inserted in larvae cells, food storers from honey comb, guards from the entrance of the hive and foragers from the entrance of the hive during emergence. Bees were frozen on ice and their digestive

tracts were discarded. The samples were processed following the protocol of Roe and Dailey (1966) for glycogen content. Each group of sample contains 20 individuals and five such replicates were taken. One-way ANOVA was performed at 0.05 significant levels. Data was expressed as µg of glycogen/bee.

Results

Lipid analysis: Lipids detected were phospholipids, cholesterol, free fatty acids, triglycerides, methyl esters and cholesterol esters from adult worker and drones (Table 1). Nurse, middle aged, foragers of worker bees revealed the presence of the same lipid classes, but they were present in different proportions, cholesterol esters were however not detected in the food storer bees. Drones also showed similar classes of lipids.

Nurse and food storers were found to have higher lipid content than middle-aged and forager bees. Large differences in triglycerides were found among all the worker task groups, with nurse predominantly containing the highest proportion, consisting of 43% of the total. Forager bees had intermediate triglycerides comprising 21% higher than the food storer with 18% and middle-aged with 7% (Fig. 1). The level of cholesterol in nurse and food storer bees was two times greater than middle-aged and forager workers.

Free fatty acids in food storer were four times greater than forager bees and methyl esters remained more or less constant in the entire task groups.

Phospholipids were found to be the most dominant lipids in drones (Fig. 2), it comprised approximately 50% of the total, in case of the food storer it was 45% of the total, the nurse, middle-aged and forager bees contained 26%, 13% and 16% of the total respectively. Cholesterol esters were found to be the next most predominant lipids in drones comprising of 21% of the total, in nurse and middle-aged bees it was 24% of the total. Other dominant lipids were triglycerides.

There were significant differences in cholesterol, free fatty acids, triglycerides, cholesterol esters and phospholipids in task based division of labour in worker bees with that of the drones at 0.05 significant level. However, there were no significant differences in methyl esters.

Sugar analysis: TLC analysis of haemolymph sugars reveals that trehalose, fructose and glucose were present in all the task groups (Table 2). However, the difference in concentration of these haemolymph carbohydrates among different task groups was significant (trehalose: $F = 34.51$, $P < 0.0001$; fructose: $F = 286.11$, $P < 0.0001$, glucose: $F = 31.54$, $P < 0.0001$; $df = 3, 15$). The descending order of sugar concentrations among task groups was found to be fructose > trehalose > glucose (Fig. 3). Total soluble sugars from different task groups also varied significantly ($F_{3, 15} = 40.27$, $P < 0.0001$). Nurse bees had least amount of total soluble sugars (7.39±0.87 µg/µl) while it was significantly high in food storer (28.93±4.51 µg/µl), middle-aged (42.59± 3.11 µg/µl) and forager bees (73.87±3.00 µg/µl) (Fig. 3). The major sugar in drone was fructose (136.19±6.24 µg/µl) followed by trehalose (67.23±1.38 µg/µl). The least amount was of glucose containing 8.93±0.75 µg/µl (Fig. 4).

One-way ANOVA revealed significant changes in glycogen content in thorax (T) ($F_{3, 19} = 132.04$, $P < 0.0001$) and abdomen (Ab) ($F_{3, 19} = 83.21$, $P < 0.0001$) of workers performing different tasks. Glycogen concentration in the T range from 3.97±0.29 - 17.52±0.42 µg/T whereas in Ab it varies from 1.26±0.03 - 5.44±0.36 µg/Ab. Nurse bees had significantly higher level of glycogen in both T (17.52±0.42 µg/T) and Ab (5.44±0.36 µg/Ab). The level of glycogen in both T and Ab significantly

declines in food storer (T = 14.75±1.11 µg/T; Ab = 2.73±0.05 µg/Ab), guard (T = 4.14±0.24 µg/T; Ab = 1.26±0.03 µg/Ab) and forager bees (T = 3.97±0.29 µg/T; Ab = 1.51±0.09 µg/Ab) (Fig. 5a, b), with no significant difference in the latter two groups. Like workers, drones also revealed maximum amount of glycogen content in T (12.24±0.15 µg/T) and lesser amount in Ab (3.71±0.15 µg/Ab) (Fig. 6).

Discussion

The present study reveals the changes in lipids and carbohydrates among workers of specific task groups and drones of *Apis cerana indica*. Among lipids, levels of free fatty acids were found highest in the food storer bees, consistent with the findings of Toth *et al.* (2005) and Crailsheim *et al.* (1992), that nurse and foragers of *Apis mellifera* have higher and lower lipid quantity, respectively. Further, forager bees were even found to have a lower amount of free fatty acids than nurse. The highest levels of free fatty acids were found in the food storer bees; which may be due to the maximum proteolytic activity at this stage (Mortiz and Crailsheim, 1987 and Szolderits and Crailsheim, 1993).

Triglycerides were higher in the foragers; this elevation in the level of triglycerides in the foragers may be due to the effect of temperature and humidity that bees experience outside the hive while foraging. Sapcaliu *et al.* (2010) suggested that when bees are exposed to high temperature and low humidity, the level of triglycerides increases two-fold. The relatively higher amount of triglycerides in outside workers is understandable, as it is the source of energy reserve and probably supports the metabolic effort during flight to some extent. Phospholipids as a whole were the most dominant lipids.

Cholesterol was significantly high in the nurse and food storer bees, however, in the middle-aged and forager bees cholesterol dropped significantly. The decrease of cholesterol in forager could be due to a reduced hypopharyngeal gland. Ritter (1990) also pointed out that differences in diet may cause variation in cholesterol levels.

During the first week of an adult worker bee's life, consumption of pollen, rich in fats and proteins is extremely high and gradually as they become older they shift to carbohydrate rich diet for energy and metabolic processes (Crailsheim *et al.*, 1992). This alteration of diet intake could potentially influence the behavioural and physiological shifts that accompany worker honeybee's behavioural development. For instance, decrease in lipid content in adult honeybee might lead to the onset of foraging (Toth *et al.*, 2005). Depletion of nutrition has also been shown to result in increase of Juvenile Hormone (Kaatz *et al.*, 1994 and Pinto *et al.*, 2000) which in turn controls foraging (Bloch *et al.*, 2002).

The changes in the profile of sugars among various temporal worker castes showed marked differences; there is an increase in the level of glucose and fructose and decrease of trehalose in forager and other task groups. The increase in concentration of glucose and fructose and concomitant decrease of trehalose level in foragers may be due to metabolic rate, as bees involved in foraging activities have high metabolic rate than intranidal task workers. Foragers actively move in and out of the hive during their excursion for collection of nectar and pollen; this requires a constant supply of sugars in the form of trehalose, fructose and glucose in the flight muscles. As trehalose cannot be produced as fast as it is consumed and since it is obtained from conversion of fructose to trehalose via first conversion to glucose (Candy *et al.*, 1997); therefore, a lowered level of trehalose in the haemolymph of foragers may be attributed to the rapid mobilization of sugars from the

haemolymph to the flight muscles. Due to lower metabolic rate, intranidal task workers are able to maintain high level of trehalose. This result is also congruent with the finding of earlier works on *Apis mellifera* (Abou-Seif *et al.*, 1993; Bozic and Woodring, 1997 and Blatt and Roces, 2001) and substantiated by the higher level of triglycerides found in the haemolymph. The changes in glycogen content are also consistent with *Apis mellifera carnica* (Panzenbock and Crailsheim, 1997) where young workers have more glycogen content than aged workers like the guards and foragers.

Table 1: TLC of lipid extract from whole adult honeybee workers (n=20), six replicates and standard lipids. Lipid extracts and standards were loaded on silica gel GF plates and were developed in petroleum ether/diethyl ether/acetic acid (90:10:1; v/v/v) according to the procedure of Mangold and Malins (1960) and Mangold (1961 and 1964). The plates were visualized in iodine chamber.

Lipid classes	Standard (R_f)	Sample (R_f)
Cholesterol	0.23±0.04	0.22
Free fatty acids	0.33±0.02	0.33
Triglycerides	0.50±0.02	0.49
Methyl esters	0.86±0.04	0.83
Cholesterol esters	0.93±0.01	0.92

Table 2: TLC of sugars of adult honeybee workers hemolymph on silica gel GF and their R_f. Plate was developed with dimethyl formamide/*n*-butanol/water (3:12:2; v/v/v) mobile phase.

Sugars	Standard (R_f)	Sample (R_f)
Trehalose	0.34	0.35
Fructose	0.72	0.73
Glucose	0.75	0.76

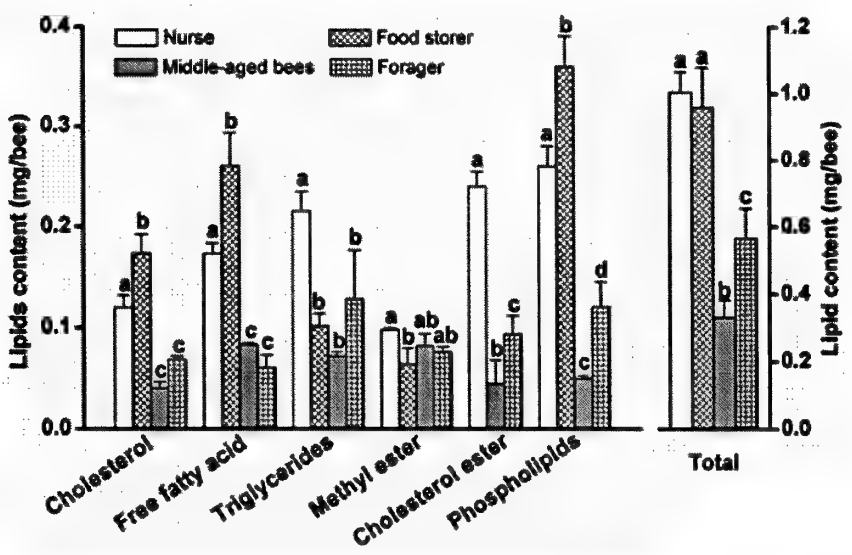

Fig. 1: Lipid class composition of total homogenates from different task groups; values are mean of six determinations ± SE; different letters on the error bars indicate significant differences, same letters indicate no significant differences.

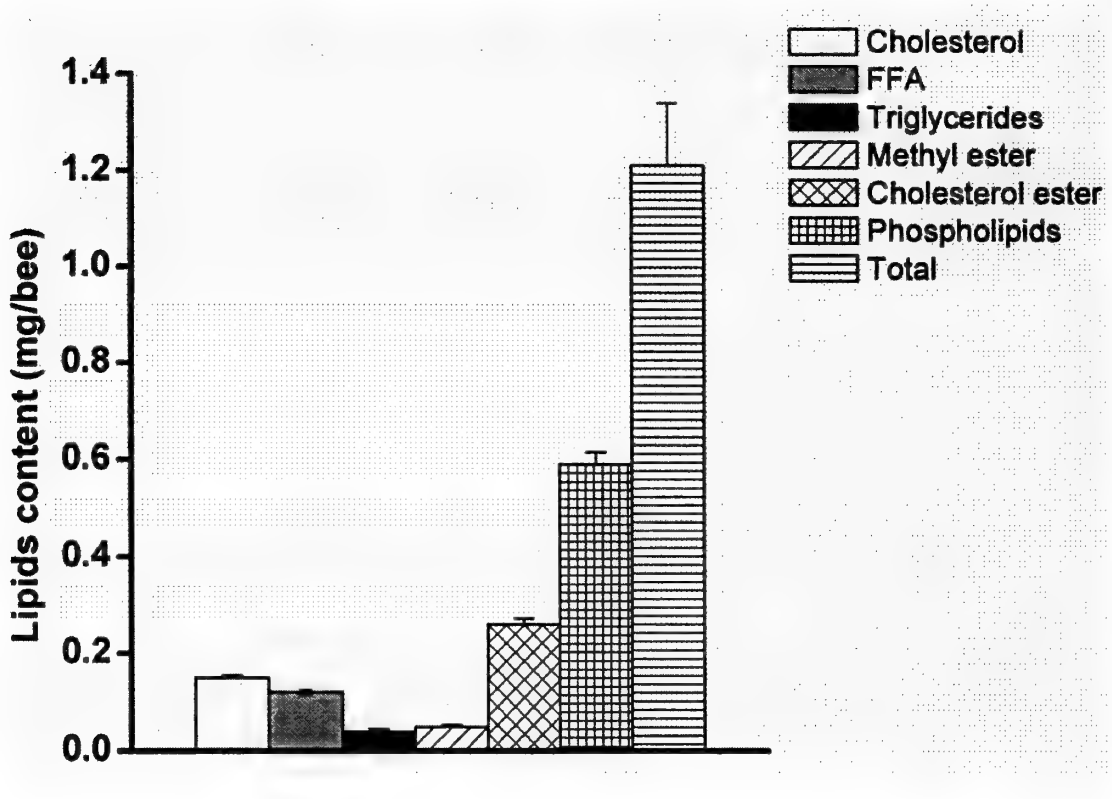

Fig. 2: Lipid class composition of total homogenates from drone; values are averages of six determinations ± SE (FFA = free fatty acids).

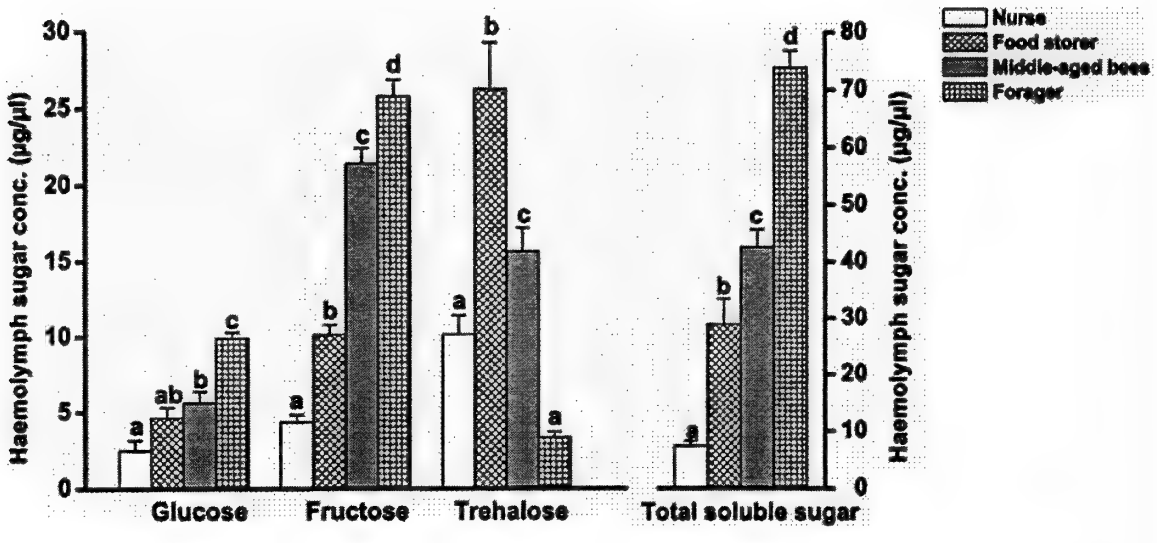

Fig. 3: Differences of sugar concentrations in different task groups of worker bee haemolymph; values are presented as mean ± SE.

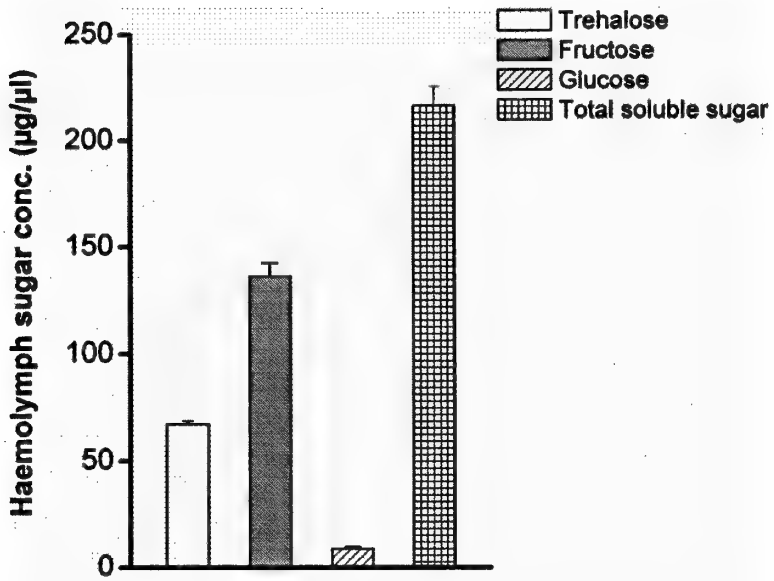

Fig. 4: Differences of sugar concentrations in drone haemolymph; values are presented as mean ± SE.

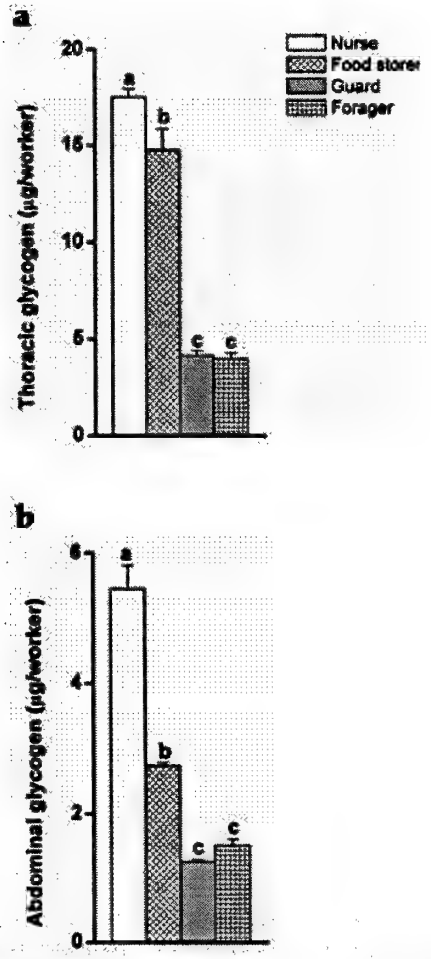

Fig. 5: Glycogen in a) thorax and b) abdomen of different task groups of workers.

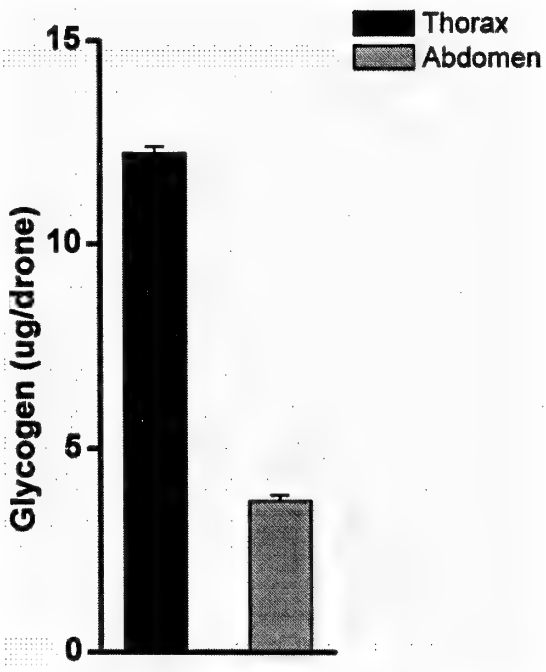

Fig. 6: Glycogen in thorax and abdomen of drones.

Acknowledgments

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SEM studies on immature stages of *Aphaenogaster beesoni* Donisthorpe, 1933 (Hymenoptera: Formicidae)

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Abstract

Larval instars of *Aphaenogaster beesoni* Donisthorpe, 1933 are herein described in detail by scanning electron microscopy. Based on the body profile, body size, types of body hairs and head capsule size a total of five larval stages are recognised. All five instars show clear variations in their body shape and mouth parts. Body of the first instar is Aphaenogastroid, while that of the second, third and fourth is Pogonomyrmecoid, and in fifth it again becomes Aphaenogastroid type.

Keywords: SEM, immature stages, *Aphaenogaster,* India.

Introduction

The ant genus *Aphaenogaster* Mayr includes 180 extant species, 45 subspecies and 19 fossil species; these ants are widely distributed in all geographical regions of the world except Ethiopian region (Bolton *et al.,* 2007; Bolton, 2013). The genus includes one of the most primitive and generalized ant species with fossil records in the Baltic amber. Currently, it is represented by 176 extant species from the World of which 14 belong to Indian region (Bharti, 2011).

The significance of larval descriptions to ant systematics has been discussed in a number of sources (Wheeler and Wheeler 1976, 1986, 1988; Fox *et al.,* 2007, 2010, 2012; Solis *et al.,* 2007, 2010a, b, 2011; Jesus *et al.,* 2010; Nondillo *et al.,* 2010; Bharti and Gill, 2011 and Bharti and Kaur, 2011). As rightly put by Wheeler and Wheeler (1976), "Modern taxonomy is complete only when variety of data is pushed as far as possible towards the limit of practicability. The object of classification should be holomorph i.e. studying all the characteristics of an individual throughout its life". Apart from their importance in the study of general biology (Peeters and Holldobler, 1992), the larval characters of ants have also been used for phylogenetic and behavioural studies (Petralia and Vinson, 1979a, b; Schultz and Meier, 1995; Masuko 2003, 2008; Pitts *et al.,* 2005 and Signorotti *et al.,* 2013).

Aphaenogaster beesoni Donisthorpe, 1933, a high altitude species is widely distributed in Northwest Himalaya. It nests under stones and is found mainly in forested areas with scarce undergrowth and fairly moist surfaces. Intensive ecological and taxonomic studies have been made on *Aphaenogaster beesoni* but there is a void in our knowledge, as far as its larval morphology is concerned.

Here we provide reliable distinguishing larval characters, to fill this gap in our understanding of *Aphaenogaster* immatures. The present study marks the first ever comprehensive study on immatures of *Aphaenogaster beesoni.* Based on ultrastructural images, minute

morphological details of different larval forms have been studied, to generate baseline data and to aid in future interspecific diagnosis.

Materials and Methods

To study the immature stages of *Aphaenogaster beesoni,* larval forms were collected from 5 different colonies located at Solang valley (2560m), Himachal Pradesh, India. The larvae were fixed in the Dietrich's solution for 24-48 hrs, and then preserved in 80% alcohol. The larvae were separated into five instars on the basis of body profile, body size, types of body hairs and head capsule size.

After separation of larval forms, all instars (n=10) were prepared for scanning electron microscopy using following steps: a) instars preserved in 80% alcohol were post fixed in 1% Osmium tetraoxide and then placed in refrigerator for 2 hours; b) after post fixing, the specimens were dehydrated in a graded acetone series; c) specimens were critical point dried in desiccators; d) dried specimens were then attached to the aluminium stubs with double faced conductive adhesive tape; e) specimens were then placed in the sputter for coating with the palladium and f) specimens were studied under a Zeiss EVOMA10 Scanning Electron Microscope at 20 KV/EHT.

The terminology given by Wheeler and Wheeler (1976) and Fox *et al.* (2007) has been used to describe the larvae of *Aphaenogaster beesoni*. As body profile of *Aphaenogaster beesoni* is of curved type, it is therefore measured as cursor width and cursor height. Body hairs are measured at full length. Head capsule width, mouthparts and other morphological characters are measured for at least twenty individuals per larval instars.

Results

The detailed description of important morphological larval characters of different instars of *Aphaenogaster beesoni* is as follows:

First larval instar

Body: Whitish, Aphaenogastroid in shape head bent ventrally, anus slightly subterminal transverse slit with 10 body spiracles (Figs. 1a, 1b). Head and body covered with abundant hairs. Mainly two types of hairs present on body surface: smooth, unbranched flexuous hairs and anchor-tipped hairs (Fig. 1c). Body length 865.3µm, width 564.1µm; body diameter at thorax region 246.6µm, at abdomen region 336.4µm (Fig. 1a).

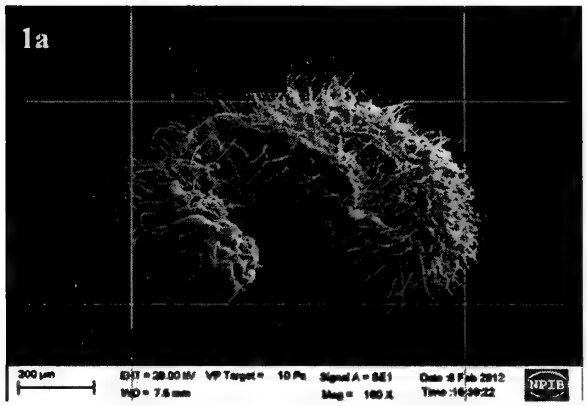
Head capsule: Cranium 224.9µm high and 278.8µm wide; roughly subcircular in shape (Fig.1d). Head surface smooth with bilaterally symmetrical tip-bifid hairs.

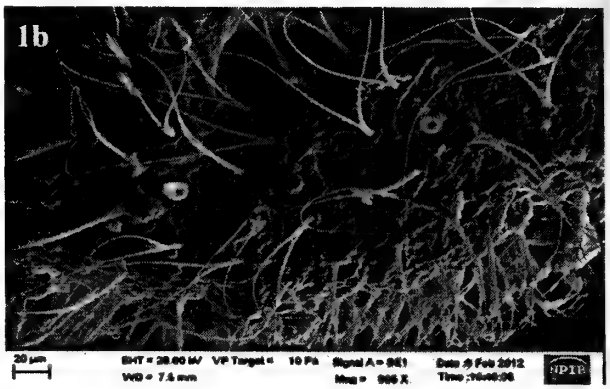
Mouthparts: Clypeus not clearly delimited from the cranium, upper surface of clypeus smooth, without sensilla, with two types of hairs: simple and tip-bifid; labrum bilobed (Fig. 1e). Mandibles simple, sharp pointed; Pogonomyrmecoid in shape, 92.38µm long and 32.55µm wide from the base with three medial teeth lying approximately in same plane (Fig. 1f).

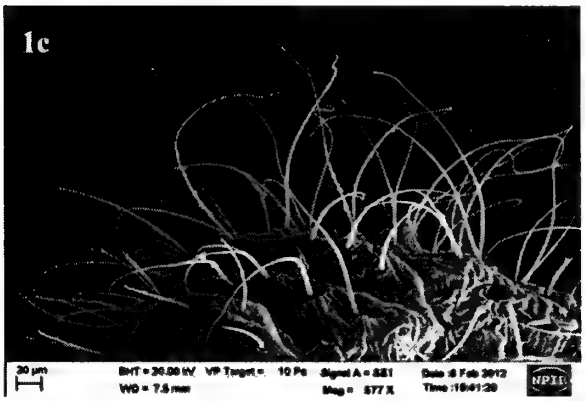
Second larval instar

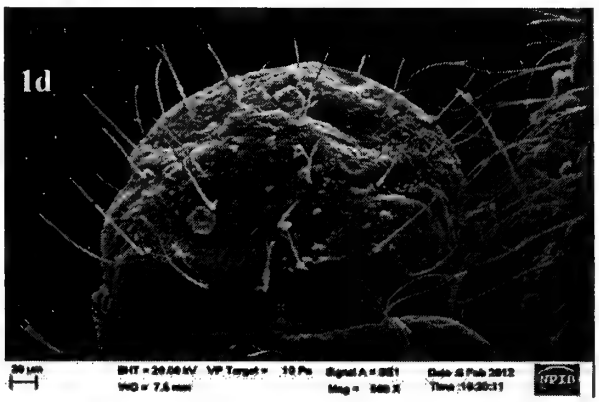
Body: Body shape changed from Aphaenogastroid in first instar to Pogonomyrmecoid in second larval instar. In this case the diameter is greatest near middle of abdomen, decreasing gradually toward head and more rapidly toward rounded posterior end; thorax more slender than abdomen, forming a ventrally curved neck (Fig. 2a). Body hairs are less as compared with the first instar larva and are of two types: deeply bifid measuring about 146.5µm and flexuous i.e. whiplike or flagelliform, measuring about 154.6µm (Fig. 2b); anus subterminal in position (Figs. 2c, 2d). Body length 1.403mm; width 949.7µm; body diameter at thorax region 300.7µm, at abdomen region 629.0µm (Fig. 2a).

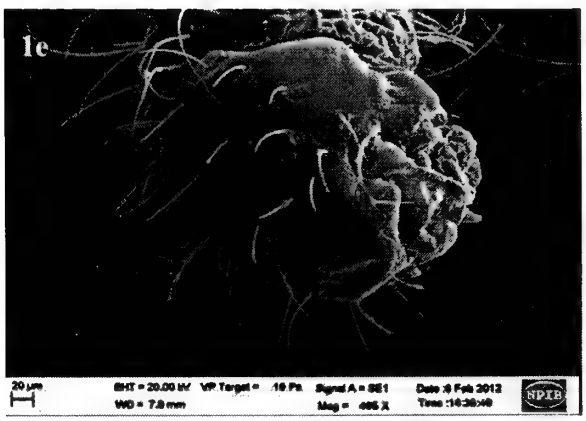
Head capsule: Cranium 230.7µm high and 290.5µm wide; antennae distinct in diameter.

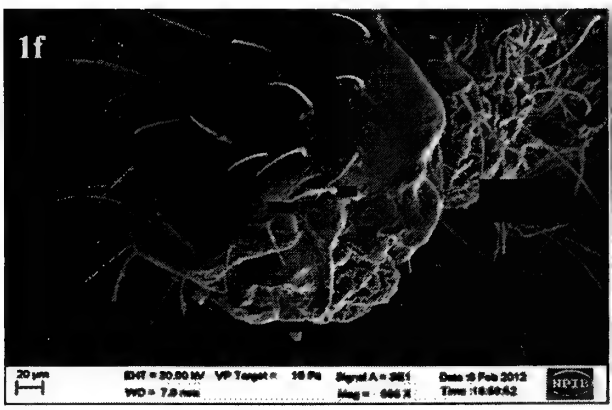




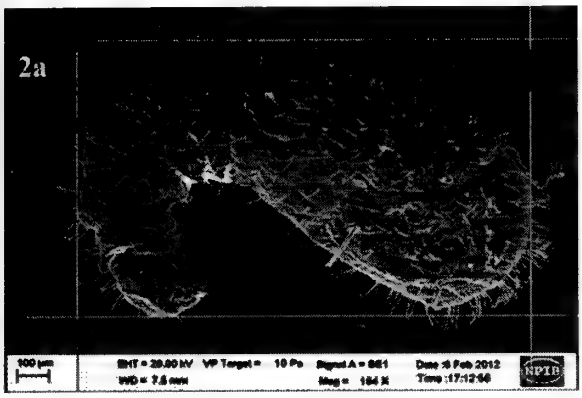


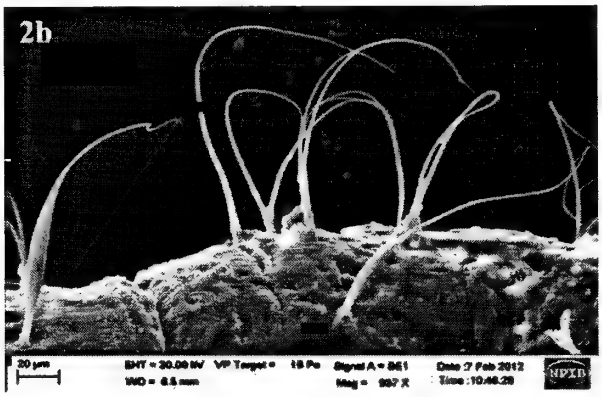


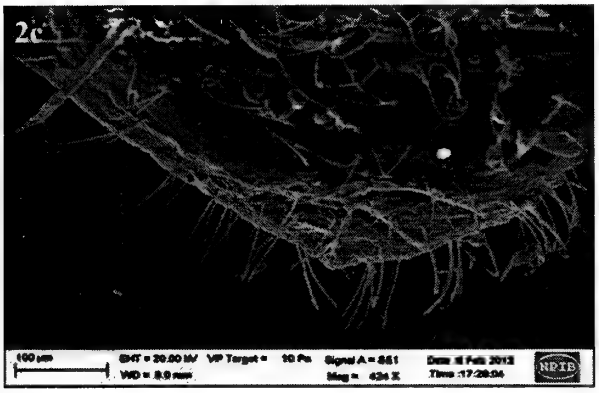


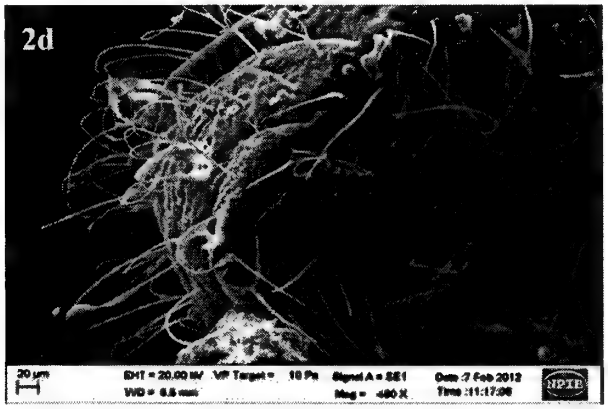


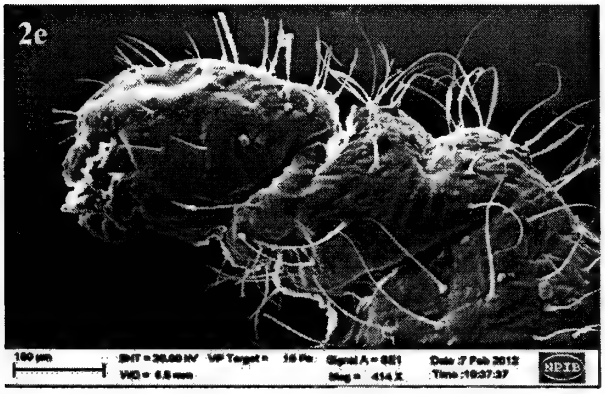
Figures 1a-f: First larval instar; *Aphaenogaster beesoni* 1a. Body profile; 1b. Abdominal spiracles; 1c. Body hairs; 1d. Head cranium; 1e, 1f. Head and mouth parts.

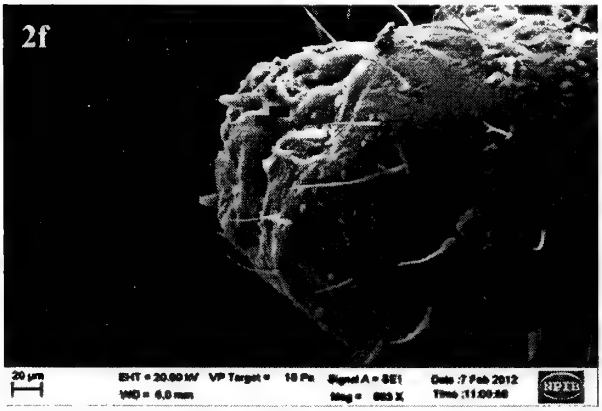












Figures 2a-f: Second larval instar; *Aphaenogaster beesoni* 2a. Body profile; 2b. Body hairs; 2c. Anal region; 2d. Body hair and anal region; 2e. Cranium and thorax; 2f. Mouth parts.

Head hairs which include simple, straight and tip-bifid hairs are present on the occipital border, on the vertex, on the genal region and on the gula (Fig. 2e).

Mouthparts: Labrum bilobed; mandibles Pogonomyrmecoid i.e. subtriangular in shape, with three conspicuous medial teeth lying in the same plane, mandibular surface spinulose. Maxillae paraboloidal, long, wide with widely spaced setaceous sensilla. Galeae simple 28.25µm long × 10.35µm wide. Labium stout and hemispherical with some scattered setaceous sensilla over the surface. Clypeus clearly delimited from the cranium (Fig. 2f).

Third larval instar

Body: Body profile Pogonomyrmecoid (Fig. 3a), anus subterminal in position. Body hairs of three types: straight, deeply bifid and dichotomously branching (Fig. 3b), more dense on the posterior surface of body. Spiracles about 1.10µm in diameter, unadorned peritreme (Figs. 3c, 3d). Total body length 677.2 µm, from thorax to anus 782.2 µm; body diameter at thorax 444.9µm, at abdomen 625.6µm (Fig. 3a).

Head capsule: Cranium 250.6µm high and 298.5µm wide. Hairs mainly two type: simple, slightly curved, long and tip-bifid. Antennae distinct, shallow pits on upper half of cranium with three sensilla (Fig. 3e).

Mouthparts: Clypeus not delimited from the cranium, surface smooth, sensilla absent. Labrum bilobed, with setaceous sensilla over the anterior surface. Mandibles wide, subtriangular, 102.9µm long × 28.61µm (Fig. 3f).

Fourth larval instar

Body: Body profile Pogonomyrmecoid (Fig. 4a), anus subterminal in position (Fig. 4b); body hairs of three types: smooth flexuous; tip bifid and deeply bifid; hairs less dense as compared to the other instars. Body length 1.980 mm, width 932.6µm (Fig. 4a).

Head capsule: Cranium 244.0µm high × 255.2µm wide (Figs. 4c, 4d). Hairs on the head are of two types: simple, slightly curved and tip bifid.

Mouthparts: Clypeus delimited from the cranium, two rows of simple slightly curved and tip bifid hairs present on the head; labrum bilobed with setaceous sensilla over the anterior surface. Mandibles long, subtriangular. Maxillae paraboloidal in shape. Galeae 25.94 µm long × 12.05 µm wide (Fig. 4e).

Fifth larval instar

Body: Body Aphaenogastroid i.e. diameter increasing gradually towards the middle of thorax and abdomen; thorax arched ventrally but not forming a distinct neck; posterior end broadly rounded (Fig. 5a). Body hairs of two types: simple 103.4µm long and slightly curved at the tip 123.5µm long (Fig. 5b); anus subterminal 415.4µm in diameter (Fig. 5c); diameter at waist 654.2µm, at thoracic region 959.7µm and at abdominal region 1084.0µm (Fig. 5a).

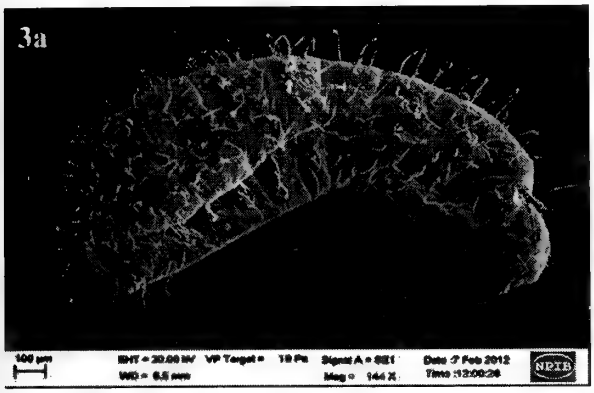
Head capsule: Cranium 763.2µm high × 985.9µm wide from upper view and 221.0µm high × 317.8µm wide from side view (Figs. 5d, 5e). Antennae present on the upper cranium measuring 44.13µm long (Fig. 5e). Hairs slightly curved and less in number (Fig. 5e).

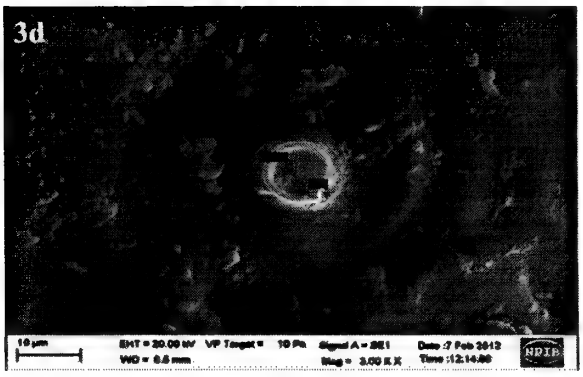
Mouthparts: Clypeus delimited from the cranium. Hairs almost absent from mouth region (Fig. 5f).

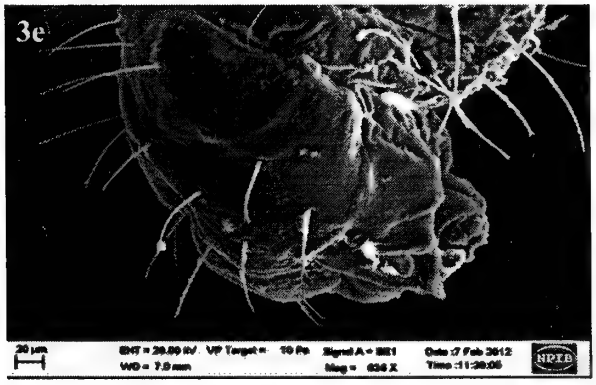
Discussion

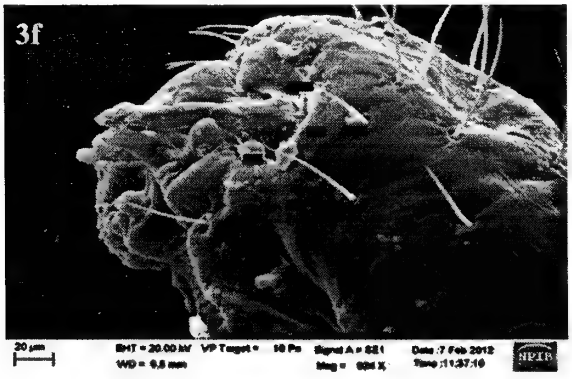
The present study marks first ever comprehensive study on immatures of *Aphaenogaster beesoni*. Using scanning electron microscopy, the larvae of species were separated into five instars; their minute details were observed and later described in detail. This division of larvae into 5 instars is carried for the very first time (Table 1 and 2).

The body profile of 1st and 5th larval instar is Aphaenogasteroid and that of 2nd, 3rd and 4th larval instar is Pogonomyrmecoid type (Figs. 1a,

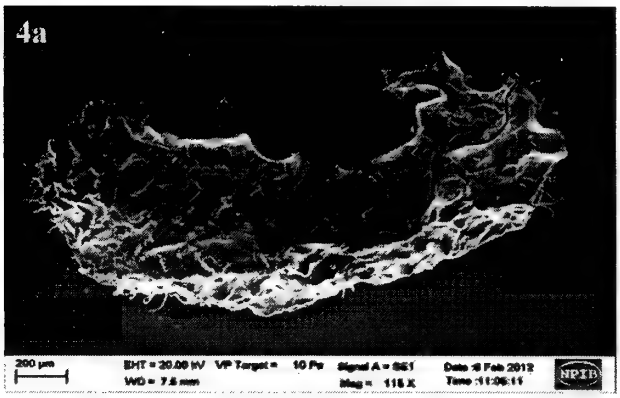


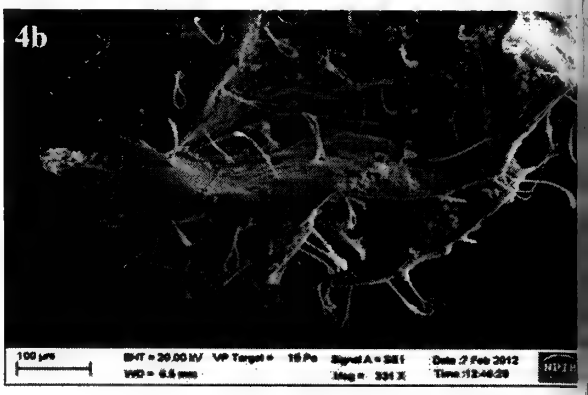


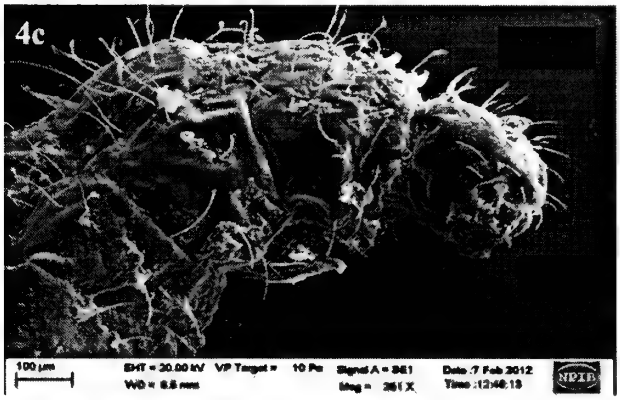


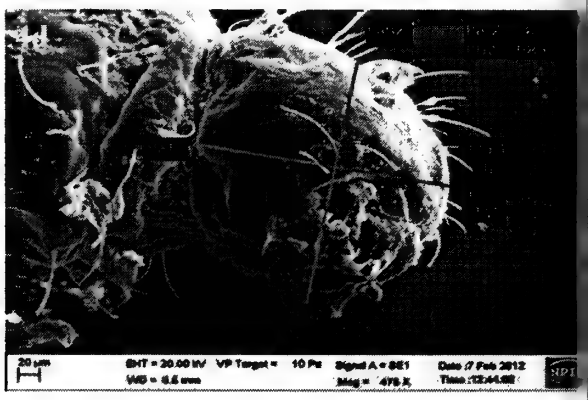


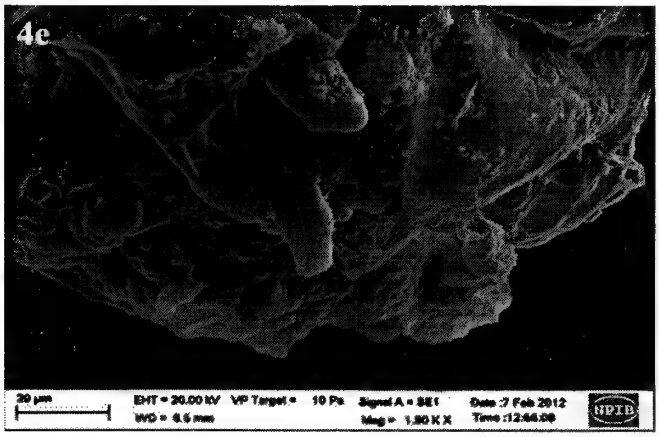
Figures 3a-f: Third larval instar; *Aphaenogaster beesoni* 3a. Body profile; 3b. Body hairs; 3c. Body spiracles; 3d. Spiracle with measurement; 3e. Cranium and sensilla; 3f. Mouth parts.



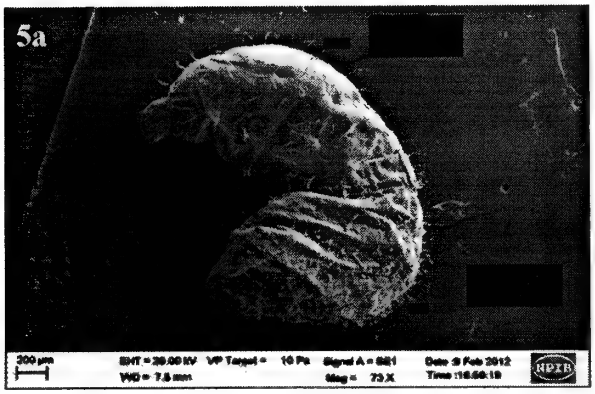


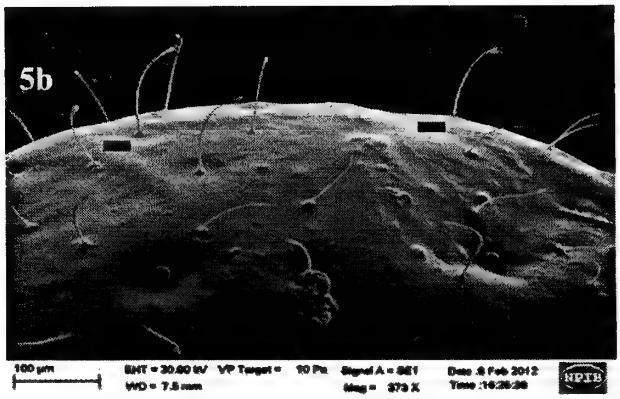


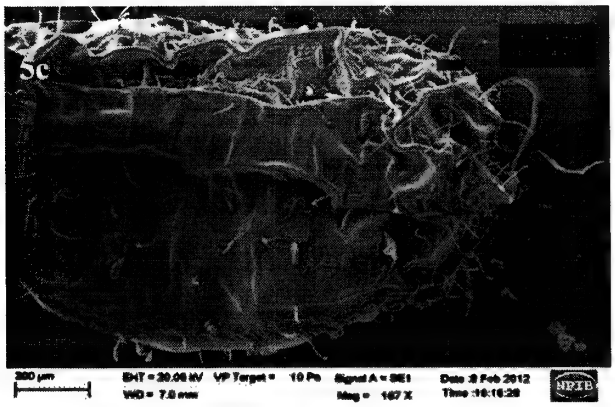


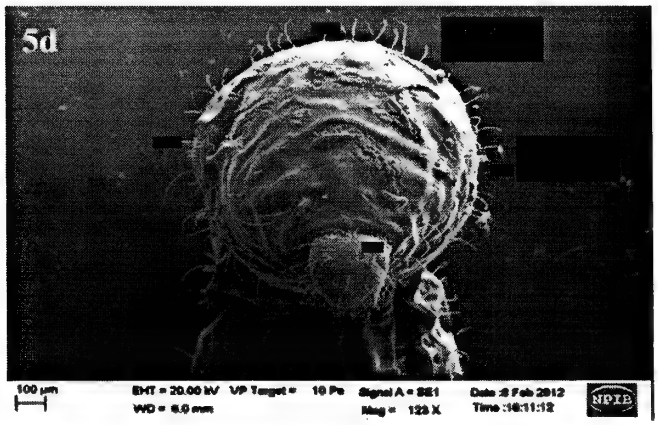


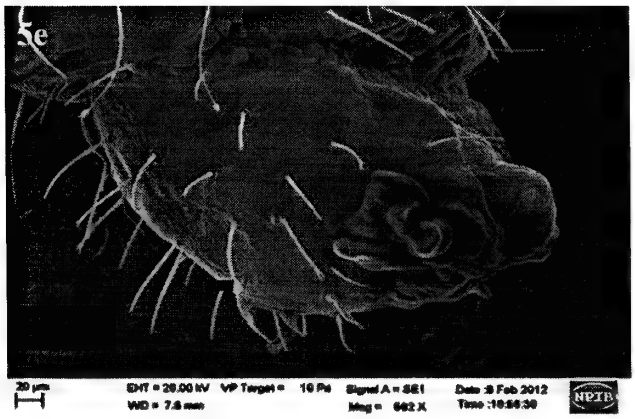
Figures 4a-e. Fourth larval instar; *Aphaenogaster beesoni* 4a. Body profile; 4b. Anal region; 4c. Thorax and cranium; 4d. Head capsule; 4e. Galeae with measurement.

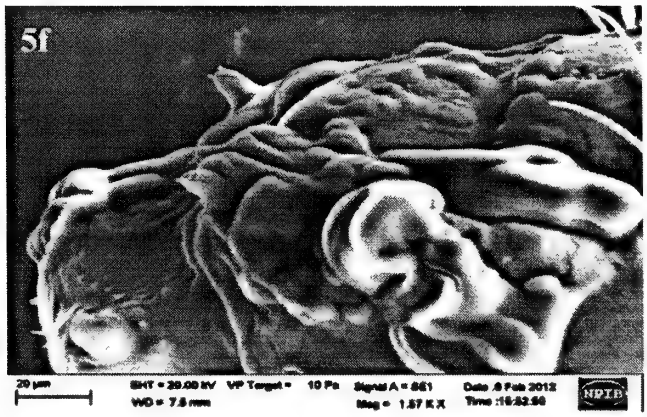












Figures 5a-f: Fifth larval instar; *Aphaenogaster beesoni* 5a. Body profile; 5b. Body hairs; 5c. Anal region; 5d. Head capsule; 5e. Antennae with measurement; 5f. Mouth region.

2a, 3a, 4a, 5a respectively). The body size of all larval instars increases as they grow. The diameter from thorax and abdomen region in all instars measured corresponds to 246.6µm : 336.4µm in 1st larval instar, 360.7µm : 629.0µm in 2nd larval instar, 444.9µm : 635.6µm in 3rd larval instar, 775.6µm : 932.6µm in 4th larval instar and 959.7µm : 1084.0µm in 5th larval instar (Figs. 1a, 2a, 3a, 4a, 5a). Anus shifts from slightly ventral in position in first instars to subterminal in rest of the larval instars (Figs. 2c, 2d, 4b, 5c).

Hair type is one of the characters considered in calculating the "specialization indices" proposed by Wheeler and Wheeler (1986). The presence of bifurcations in the head hairs is being recently proposed as a character of considerable importance for separating species in the genus *Solenopsis* Westwood (Pitts, 2005). Fox *et al.* (2007) pointed out that intraspecific variation in types of head hairs might occur in other ant species as well; the present study is in accordance with the above study and suggests the revision of all the previously described ant larvae. Two types of hairs observed on the body and head surface of immature larval instars include:

Simple Hairs: Present on body and head surfaces of almost all larval instars and are further of two subtypes:

(i) Slightly curved or straight, present on head and body of all instars.

(ii) Flexuous, present on the body of 1st and 2nd larvae and absent on head region.

Bifid hairs: These also have two subtypes:

(i) Tip bifid, observed on head surfaces of almost all instars but were only present on the body surfaces of 1st and 3rd larval instars.

(ii) Deeply bifid, branched long and flexuous hairs, observed on body surfaces of all instars (Figs. 1c, 2e, 2f, 3c, 3e, 4d, 5b).

Size of cranium of larval instars increases as they grow in size; measurements of cranium of all instars corresponds to 224.9µm high × 278.8µm wide in 1st larval instar, 234.6µm high × 289.6µm wide in 2nd larval instar, 239.0µm high × 294.4µm wide in 3rd larval instar, 244.0µm high × 305.2µm wide in 4th larval instar and 251.0µm high × 317.8µm wide in 5th larval instar (Fig. 1d, 2e, 3e, 4c, 5d).

Clypeus is not clearly delimited from the cranium in all larval instars. Labrum is bilobed in all larval instars. Mandibles are simple, sharp, pointed and Pogonomyrmecoid in shape with three medial teeth approximately in same plane and increase in size from 1st larval instar to the 5th larval instar. Mandible measured in the first larval instars is 92.38µm long × 32.55µm wide from base. In third larval instar it is measured as 102.9 µm long × 38.91µm wide from base (Figs. 2f, 3f).

Maxillae and maxillary palps of all the five instars are found to be very distinct. As the growth proceeds in larvae the mouth parts also increase in size. Galeae measurements of 2nd and 4th larvae are 28.25µm long × 10.35µm wide and about 35.94µm long × 12.05µm wide (Fig. 2f, 4e).

The details added to the larval description of *Aphaenogaster beesoni* will provide an insight into minute details of immature stages and aid in future interspecific diagnosis.

Table 1: Hair types observed in larvae of *Aphaenogaster beesoni.*

Hair type	Subtypes	Description	Location on instars (L)	
			Body	Head
Simple (S)	S1	Slightly curved/straight	All instars	All instars
	S1	Flexuous	L1*, L2*	Absent
Bifid (B)	B1	Tip bifid	L1*, L3*	All instars
	B2	Deeply bifid branches long and flexuous	All instars	Absent

* = (L1) First instar, (L2) Second instar and (L3) Third instar

Table 2: Body measures of different instars of *Aphaenogaster beesoni.*

Observed Structures		Larval instars				
		1st	2nd	3rd	4th	5th
Body Types		Aphaenogasteroid	Pogonomyremocoid	Pogonomyremocoid	Pogonomyremooid	Aphaenogasteroid
Body Width	Thorax	246.6µm	360.7µm	444.9µm	775.6µm	965.4µm
	Abdomen	336.4µm	629.0µm	635.0µm	932.6µm	1084.0µm

Acknowledgements

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ISSN 0973-1555 © KELOTH RAJMOHANA AND MANIKANTADAS SANTHA NISHA

Telenomus oryzae (Hymenoptera: Platygastridae), a new egg parasitoid of the rice black bug, *Scotinophara* (Heteroptera: Pentatomidae) from India

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Abstract

***Telenomus oryzae* (Hymenoptera: Platygastridae), an egg parasitoid of the rice black bug on rice from India is described as new to science. The species has a wide distribution in the rice fields of the South Indian State of Kerala. Illustrations of *T. oryzae* sp. nov. are provided and its affinities with other species are discussed. *T. cyrus* Nixon, the closely related species, is redescribed based on the holotype and paratypes. A key to species of *podisi* group of *Telenomus* of Oriental Region, the group parasitizing the eggs of pentatomid and scutellerid bugs is also appended.**

Keywords: *Telenomus, India, rice black bug, egg parasitoid, new species.*

Introduction

Telenomus spp. attacking the eggs of Pentatomidae and Scutelleridae (Heteroptera), belong to '*podisi*' species group (Johnson, 1984). In Oriental Region, only two species of *Telenomus*: *T. triptus* Nixon, 1937 and *T. cyrus* Nixon, 1937 (Johnson, 1984) are known to attack the pentatomid eggs.

The Rice black bug is a highly invasive pentatomid heteropteran, attacking various growth stages of the rice plant and has now a significant status as a potential pest of rice in many countries, including India (Narayansamy, 2007). Ambikadevi (1988) had reported the incidence of *Scotinophara bispinosa* at Kuttanad rice fields of Kerala in Alappuzha, one of the study areas of the present work. On a global scale, of the 6 species of egg parasitoids reported from the eggs of the rice black bugs, 3 species belong to *Telenomus*: *T. triptus* Nixon, *T. chloropus* (Thomson, 1860) and T. *gifuensis* Ashmead, 1937 (Polaszek and Rajmohana Kumar, 2007). Here we report a new species, *Telenomus oryzae* as an egg parasitoid of the rice black bug on rice from Kerala and Tamilnadu.

Materials and Methods

This work is a part of the ongoing studies (Rajmohana and Narendran, 2007 and Rajmohana, 2010) on the systematics of Telenominae (Hymenoptera: Platygastroidea) of India.

Morphological terminology follows Masner (1979) and Johnson (1984). Male genitalia slides were prepared as per Polaszek and Kimani (1990). The notes on holotype and paratypes of *T. cyrus* are excerpts from the studies (unpublished) on

Nixon's types of Telenominae made by the first author, in 2007, during a study visit to BMNH, London.

The description and imaging was conducted using Leica M205A stereomicroscope and Leica DFC-500 digital camera. The SEM images were procured with Jeol JCM-5000 NeoScope Benchtop SEM, using specimens coated with gold.

All the material studied is deposited in National Zoological Collection, of Zoological Survey of India, Calicut.

Abbreviations and Terminology: A1-A11: Antennal segments 1 to 11; T1-T4: Metasomal tergites 1 to 4; L: Length; W: Width; DCI: Dorsal Cephalic Index (ratio of width to length of head measured dorsally LOL: Lateral ocellar length; POL: Posterior ocellar length; BMNH: British Museum of Natural History, London; NZC: National Zoological Collection; ZSIC: Zoological Survey of India, Calicut, Kerala.

Systematics

Telenomus oryzae sp. nov.
(Figs. 1 -9)

Material examined: Holotype; ♀ (Reg. No. ZSI/WGRC/T8) INDIA: Kerala: Edathara (24 km from Alappuzha) Alappuzha (9.43527 N, 76.421667 E), 12.viii.2008, emerged from *Scotinophara* eggs on rice, coll. M.S. Nisha. Paratypes; 24 (Reg. No. ZSI/WGRC/T9-33) 3♀ and 1 ♂ with same data as that of the holotype; 5 ♀ and 1 ♂ INDIA: Kerala: Wayanad: Madakkimala (11.39651 N, 76 05318 E) (paddy field), 19.xii.2008 and 1 ♀ on 9.i.2009 from the same locality; 2♀ INDIA: Kerala: Malappuram: Nilambur; Kavalamukkatta (11.15132 N, 76.21174 E) (paddy field), 16.ix.2008 and 1 ♀ same locality, 30.ix.2008; 3 ♀ INDIA: Kerala: Calicut: Peruvayal (11.15178 N, 75.54237 E) (paddy field), 2.i.2009, 2 ♀ and 1 ♂ on 11.xii.2008 same locality, coll. K. Rajmohana. 4♀ INDIA: Tamilnadu: Neikuppam (12.78 N and 79.8183 E) (paddy field), 14.xii.2010, malaise trap coll. S. Divya.

Description

Holotype: Female; body length 0.9-1.01 mm. Head and body black; all coxae yellow; rest of legs also yellow; terminal tarsal segments and claws brownish black; radicle, antennal scape and pedicel ventrally yellow; pedicel dorsally and rest of antenna brownish black; eyes and ocelli silvery; wings hyaline, veins brown.

Head (L:W = 18:39); distinctly transverse; DCI = 2.16; vertex and occiput with fine coriaceous reticulate sculpture, steeply angled down to occiput; hyperoccipital carina seen as a trace beneath lateral ocelli, not continuous medially; occipital carina interrupted medially; occiput between hyperoccipital and occipital carina with same coriaceous sculpture as that on vertex; frons anterior to median ocellus smooth, but with a faint patch of coriaceous sculpture at median part above toruli; ocellar setae 1 pair, widely separated; orbital band wide and extending throughout, not interrupted medially; frontal pit present; frontal depression indicated; frons bulging between antennal insertions and inner orbits (best visible when viewed from above); ratio of frons width to eye height = 1.06; eyes with very fine sparse setae; inner orbits angled at level of lateral ocelli; lateral ocelli contiguous with orbital margin, connected by a wide sulcus posteriorly; post ocellar groove behind lateral ocelli distinct; grooves not meeting medially; LOL:POL = 8:15; malar space smooth, sulcus distinct; temples not bulging, hardly visible in dorsal view; gena and temples smooth except for narrow coriaceous band along posterior orbits, extending towards occiput; antenna 11

segmented in females; radicle small, less than A2 2x as long as wide, A3 (first funicular segment) elongate, 2.5x as long as wide and distinctly longer than pedicel; length of A3 > length of A2 (1.13x) and A3 length > A4 length (1.5x), A4 length 1.2x length of A5; A5 and A6 subequal; A7-10 quadrate; length of A2:A3:A4:A5 = 23: 26:17:14.

Mesosoma (L:W= 36:33), not as wide as head dorsally (0.83x); mesoscutum convex, with rough scaly reticulations; sculpture finer posteriorly towards scuto-scutellar sulcus; sulcus foveolate and wider laterally; finely crenulate medially; humeral as well as supra humeral sulcus foveolate; mesoscutellum smooth, with dense long setae; metascutellum punctate reticulate, longest medially and overlapping propodeum; acetabular carina simple; episternal fovea absent; intercoxal space greater than length of forecoxa; netrion feebly indicated; mesopleural furrow well developed; mesopleural carina absent; metapleural carina notched, well developed only in posterior half; forewing at rest surpassing apex of metasoma; basal vein not pigmented; postmarginal vein much longer than stigmal; hindwing at its widest point 1.8x length of marginal fringe; forewing L:W= 26:9.

Metasoma (L:W= 35:25); T1 with 2 pairs of sublateral and 3-4 pairs of lateral setae; greatest length of basal costae on T2 about 2x median length of T1, with fine wrinkles extending even beyond; relative proportions of length of T1 and T2 being 2:15.

Male; body length 0.9 mm. Identical to female, differing only in normal secondary sexual characters. A3 and A4 of antenna elongate; A3 1.7x as long as wide; A4 1.83x as long as wide and longer than all segments other than scape.

Male genitalia; aedeagal lobe medially drawn, tapered and truncate towards tip; laminae volsellares sclerotised; aedeago-one-third length of scape; clava 5 segmented; volsellar shaft concave lateromedially; digitus small, digiti 4.

Host: Emerged from eggs of *Scotinophara* spp. (Heteroptera: Pentatomidae).

Etymology: The species is named *'oryzae'* after the host plant (paddy) of the host bugs.

***Telenomus cyrus* Nixon, 1937**

Length 1.26 mm; head and body black; coxae blackish brown, rest of legs yellowish brown; antenna uniformly dark in colour, blackish brown, scape a bit paler; wings hyaline. DCI = 2.09; vertex rounded to occiput, thought slightly angled in lateral view; coriaceous throughout, with scattered superimposed setigerous punctures; post ocellar groove distinct; hyperoccipital carina present as a trace, not complete medially; occiput coriaceous near vertex; occipital carina not complete medially; orbital bands wide and not interrupted near mid-point of eyes; frons otherwise smooth; ocellar seta present; frontal depression distinct, frons bulging between antennal insertions and inner orbits; eyes with sparse fine setae; inner orbit feebly angled at level of lateral ocelli; ratio of frons width to eye height (measured in front view) = 1.04; malar space coriaceous, temples not bulging; coriaceous sculpture along posterior orbits extending halfway distance to occipital carina; temples hardly visible in dorsal view; antenna with 11 segments, A3 elongate, distinctly longer than A2 (8:7) and A4; A5 and A6 nearly subequal; clava 5 segmented, claval segments not transverse.

Mesoscutum length and width nearly subequal; convex, coriaceous; scutellum smooth, setose, metascutellum punctate-reticulate throughout, longest medially, slight overlapping propodeum (visible in lateral view); acetabular carina simple; episternal foveae absent; width of intercoxal space less

than length of forecoxa; mesopleural carina absent; mesopleural furrow feebly developed; posterodorsal corner of metapleuron not expanded; metapleural carina distinct; forewing surpassing tip of metasoma; marginal fringe short, hindwing at widest point 2.5x length of marginal fringe at that point.

Metasoma 1.35x as long as wide. T1 with 2 sublateral and 3 pairs of lateral setae; greatest length of basal costae on T2, more than (nearly twice), medial length of T1.

Discussion

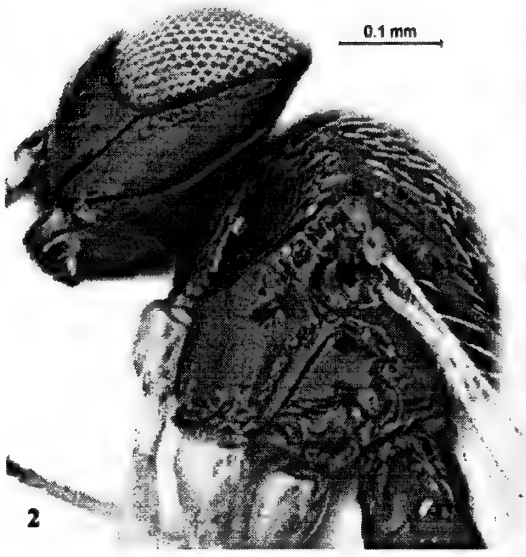
The species of *Telenomus* from China (Wu *et al.,* 1979 and Wu and Chen (1980 and 1985) were reared from eggs of Lepidoptera and hence do not belong to *podisi* group. As mentioned by Johnson (1996) in world revision of *Paratelenomus* Dodd, the characters mentioned in the descriptions of the Vietnamese species (Le, 1993 and 2000) are of little value in the diagnosis of the species. However, as per the original figures, the Vietnamese species *Telenomus lubitus* Le, 1993, described from *Scotinophara lurida*, the aedegal lobe of the male genitalia is not medially drawn as that in *T. oryzae* sp. nov.

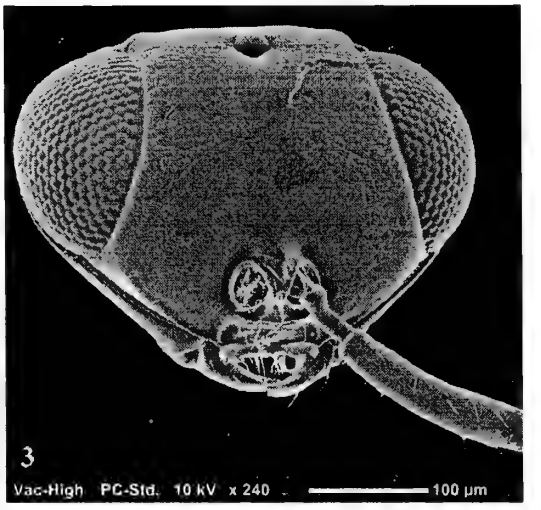
Telenomus oryzae sp. nov. keys to *T. cyrus* (couplet no. 2 and couplet no. 16) in the key to Asiatic species of *Telenomus* by Nixon (1937 and 1940), however, does not fully comply with the description of *T. cyrus*. In the key to egg parasitoids of *Scotinophara* spp. by Polaszek and Kumar (2007), the new species keys to couplet 5, but does not fit either to *T. chloropus* (in legs being yellow and not black, proportion of basal antennal segments also differing) or to *T. cyrus*.

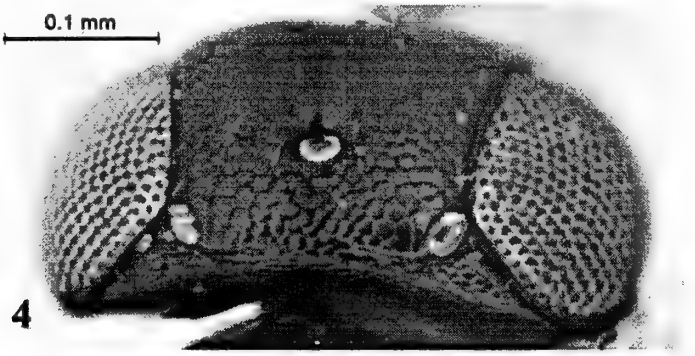
The combination of characters differentiates *T. oryzae* sp. nov. from *T. cyrus: T. oryzae* has yellow coxae; antenna is bicoloured, with entire scape and pedicel in part yellow, rest of antenna brownish black; antennal segments A5 and A6 are subequal; metasoma is only 1.35x as long as wide while in *T. cyrus* coxae are fully dark, almost black; antenna is unicolorous, dark brown or black throughout; antennal segment A5 longer than A6; metasoma is 1.5x as long as wide. Hindwing at its greatest width is less than 2x length of marginal fringe at that point in *T. oryzae*, while the same ratio is more than 2.5x in *T. cyrus*.

With the aedeagal lobe of male genitalia medially drawn and tapered, the central projection is much prominent, thus the genitalia structure of *T. oryzae* is different from that of *T. cyrus* or T. *triptus,* where central projection is not prominent.The male genitalia of *T. cyrus* resembles that of *T. triptus* as in Nixon (1940) and Polaszek and Rajmohana (2007).

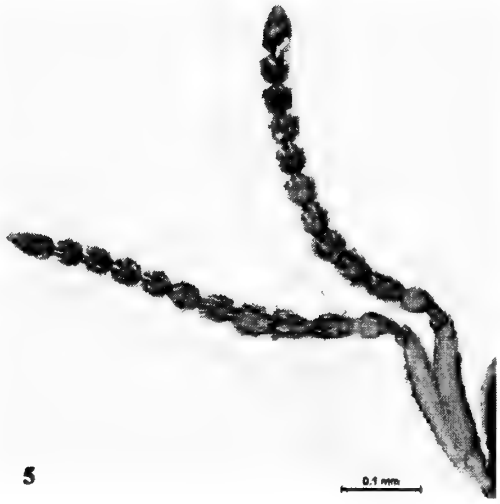
The following combination of characters serve as a diagnosis for *T. oryzae* sp. nov: body robust and black; all coxae yellow, both male and female antenna bicoloured, with scape and ventral A1 yellow and rest dark brown to black; in females A3 elongate, distinctly longer than A2 and A4; A5 and A6 subequal; orbital band with coriaceous sculpture uninterrupted, hyper occipital carina present only as a trace laterally, vertex deeply angled to occiput, post ocellar furrows present, scaly reticulate sculpture on median mesoscutum fading towards scutoscutellar sulcus, scutellum smooth and shiny with long dense setae, metascutellum punctate reticulate, longest medially and overlapping propodeum; hindwing at its greatest width less than 2x length of marginal fringe at that point; T1 with 2 sublateral setae; T2 with longitudinal striae on its basal one-third, male genitalia with a medially tapering and truncate aedeagal lobe, length of tapered part being less than length of digiti.

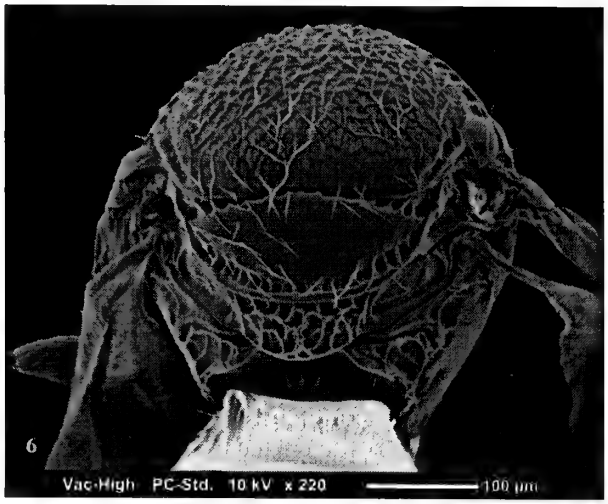


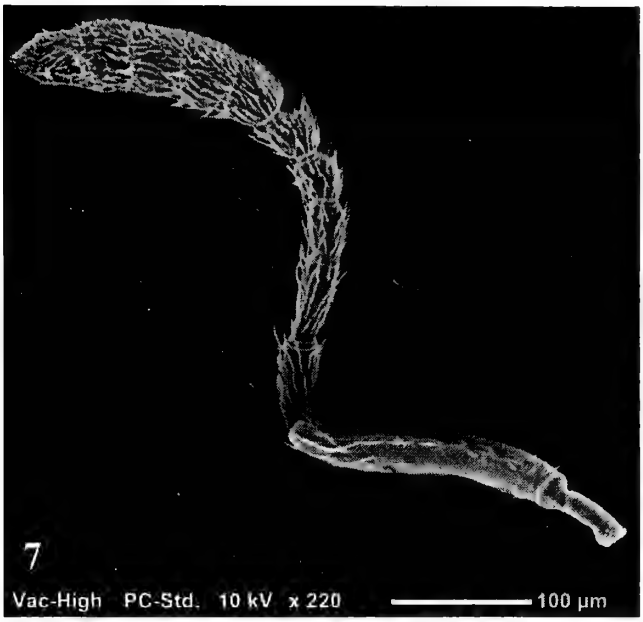


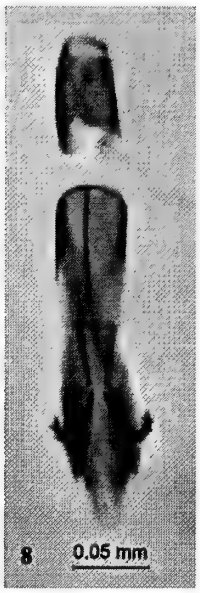


Figs. 1-4: *Telenomus oryzae* sp. nov. (1) Body, lateral view; (2) Head and Mesosoma, lateral view; (3) Head, full-face view; (4) Head, dorsal view.









Figs. 5-8: ***Telenomus oryzae*** **sp. nov. (5) Male antenna; (6) Mesosoma, dorsal view; (7) Female antenna; (8) Male genitalia.**

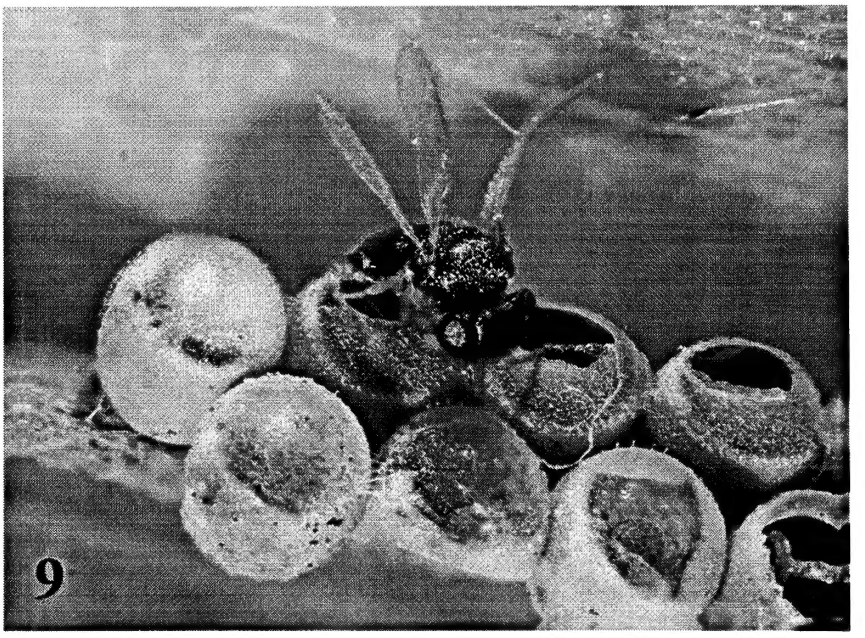


Fig. 9: *Telenomus oryzae* sp. nov. emerging from eggs of *Scotinophara* sp.

Key to '*podisi*' species group of *Telenomus* from Oriental Region

1. A3 of female antenna shorter than pedicel and < 2x as long as wide .....***T. triptus* Nixon**
-. A3 longer than pedicel and > 2x as long as wide.....2
2. All coxae yellow; hindwing at its greatest width less than 2x length of marginal fringe at that point.....***T. oryzae* sp. nov.**
-. All coxae black; hindwing at its greatest width > 2.5x length of marginal fringe at that point.....***T. cyrus* Nixon**

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