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RESEARCH ARTICLE

Phenology and Parasitization Behaviour of *Telenomus cuspis* (Hymenoptera: Platygastridae) an Egg Parasitoid of *Helopeltis antonii* (Hemiptera: Miridae) in Cashew

K. K. Srikumar · P. S. Bhat · K. Vanitha · K. Rajmohana · T. N. Raviprasad

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Abstract Population dynamics of the egg parasitoids of the tea mosquito bug, *Helopeltis antonii* was investigated between June 2010 and May 2013. Three species of egg parasitoids attacked *Helopeltis* spp. in cashew orchards viz. *Telenomus cuspis* Rajmohana and Srikumar, *Chaetostricha* sp. and *Erthymelus helopeltidis* Gahan. *T. cuspis* was the most abundant species and was recorded throughout the year with the exception of March and April. It showed the maximum parasitism rate during the monsoon (28.21 %), exhibiting a significant and positive correlation with rainfall ($r = 0.33$). The occurrence of *Chaetostricha* sp. and *E. helopeltidis* was occasional (1.80 and 2.25 %, respectively) during December, showing a significant and negative correlation with the minimum temperature ($r = -0.63$). The development time of *T. cuspis* was 20.6 ± 1.13 days. Longevity was significantly shorter for male (2.83 ± 0.16 days) than for female (4.52 ± 0.11 days). Elements of parasitoid foraging behaviour such as antennal drumming, ovipositor insertion, egg marking, walking and resting were also observed. The level of parasitism provided by *T. cuspis* suggests a good potential for biological control against *Helopeltis* spp.

Keywords Cashew · *Helopeltis antonii* · *Telenomus cuspis* · Biological control

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K. K. Srikumar (✉)
Department of Entomology, Directorate of Cashew Research, Puttur, Dakshina Kannada 574 202, Karnataka, India
e-mail: sreeku08@gmail.com

P. S. Bhat · K. Vanitha · T. N. Raviprasad
Directorate of Cashew Research, Puttur 574 202, Karnataka, India
e-mail: pshivarama59@gmail.com

K. Vanitha
e-mail: vanis102@gmail.com

T. N. Raviprasad
e-mail: tnrprasaad@gmail.com

K. Rajmohana
Western Ghat Regional Centre, Zoological Survey of India, PO Eranhipalam, Calicut 673 006, Kerala, India
e-mail: mohana.skumar@gmail.com

Introduction

Phytophagous insects of the genus *Helopeltis* (Hemiptera: Miridae) are considered as serious pests of cashew (*Anacardium occidentale* L.), cocoa (*Theobroma cocoa* L.), neem (*Azadirachta indica* A. Juss), guava (*Psidium guajava* L.), tea (*Camellia sinensis* L. O. Kuntze), black pepper (*Piper nigrum* L.) and cinchona (*Cinchona* spp.) in the Old World tropics. *Helopeltis antonii* Signoret commonly called as tea mosquito bug (TMB) is considered as major pest of cashew in India. The pest population increases rapidly and causes total yield loss [1] by directly damaging tender shoots, inflorescence, immature nuts and apples at various stages of development. Females lay eggs on young shoots, petioles, ventral midribs of leaves, inflorescence stalks and developing apples and nuts. The eggs are white, ovo-elongate with about 1.0 × 0.3 mm in size, laid deeply concealed into the plant tissue singly or in small groups, with the operculum and respiratory filaments exposed [2]. The intra-chorionic air forms a continuous layer held between vertical struts about 0.7 µm long that separates a thin inner sheet of chorion from the main body of the shell [3]. *H. antonii* eggs are often attacked by a range of

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hymenopteran parasitoids such as *Telenomus* sp. (Hymenoptera: Platygastridae), *Ufens* sp. and *Chaetostricha* sp. (Hymenoptera: Trichogrammatidae), *Erythmelus helopeltidis* Gahan and *Gonatocerus* sp. (Hymenoptera: Mymaridae) [4]. The solitary egg parasitoids, *Telenomus* sp., *Chaetostricha* sp., *Ufens* sp. and *E. helopeltidis* regulate *Helopeltis* spp. on cashew, cocoa and neem in Oriental countries [5, 6]. Egg parasitoids of the genus *Telenomus* and *Erthymelus* are particularly promising because of their host specificity [7]. In Malaysia, *E. helopeltidis* has been reported to parasitize up to 36 % of the fertile eggs of *H. cinchonae* on tea [8] and 11–47 % of the eggs of *H. theivora* on cocoa [9]. Parasitism by *Telenomus* sp., is always negligible in the eggs of *H. antonii* laid on neem and is totally absent in east coast of Tamil Nadu, while it is a dominant species in cashew ecosystems of west coast India [1]. The meteorological parameters play an important role in the population of *Telenomus* sp., exerting enhanced natural control of *H. antonii* on cashew in the west coast [10]. Recently, the recorded *Telenomus* species parasitizing eggs of *H. antonii* was identified as a new species: *Telenomus cuspis* Rajmohana and Srikumar [11].

Chemical control measures are widely adopted for management of *H. antonii* on cashew [12]. There is potential restriction in the USA and European Economic Community (EEC) countries for import of cashew kernels containing pesticide residues. Hence developing integrated pest management (IPM) plans with main emphasis on non-insecticidal control methods is required [5]. In view of the allegedly ecocidal episode of endosulphan in managing cashew pests in North Kerala, Mahapatro [13] has emphasized an IPM package for managing the pest. Recent studies on predatory ant (*Oecophylla smaragdina* Fabricius) [14] and reduviid (*Rihirbus trochantericus* Stal. var. *luteous*) [15] against *Helopeltis* spp. provided more glow on the improved biological control investigations. But, since these insects are not specific to *Helopeltis* or even the Miridae, their potential value as biological control agents is questionable. The inclusion of the parasitoid assemblage associated with a target pest in its region of origin is one of the important steps in classical biological control program [16]. Because parasitoids are more specific than predators and sometimes efficient enough to cause up to 95 % reduction of the host population, they have been extensively deployed as biological control agents [17]. Hence, the specific objectives of present study were (1) to record the species diversity of egg parasitoids of *H. antonii*., (2) to assess parasitoid seasonal occurrence in relation to meteorological parameters, and (3) to determine their population dynamics and biological and behavioural parameters.

Material and Methods

Sampling Procedures

The current study was undertaken from June 2010 to May 2013 at the Directorate of Cashew Research, Puttur and Experimental station, Shanthigodu (12°45′N latitude, 75°4′E longitude and 90 m a.s.l) in Dakshina Kannada province, Karnataka, South India. Daily field surveys were conducted randomly for the consecutive 3 years during morning hours (8.00 AM to 10.00 AM) in cashew orchards. Cashew plant parts (shoot, petiole, leaf midrib, inflorescence rachii, fruits and tender nuts) containing eggs of *Helopeltis* spp. were collected by hand picking method randomly from ≤20 cashew trees infested by *H. antonii* and brought to laboratory in polyethylene bags. At field, presence of eggs were easily detected by the existence of two respiratory filaments exposed from the oviposition sites on the respective cashew plant parts. Eggs were counted using a stereomicroscope and the plant part hosting the egg was treated in carbendazim (methyl benzimidazol-2-ylcarbamate, 0.1 %) solution for 10 min to prevent any fungal growth. After treatment, samples were dried to remove the dampness of carbendazim solution and placed in a plastic container (250 ml) fitted with a glass tube (7.5 × 75 mm) under laboratory conditions (temperature 26–28 °C; relative humidity 89–94 °C). The container (except the glass tube) was completely wrapped with black paper. The percentage of parasitism was calculated on monthly basis as per following formula.

$$\text{Parasitism } \% = \frac{\text{Total number of parasitoids emerged per month}}{\text{Total number of eggs collected per month}} \times 100$$

Emerged parasitoids were identified and deposited at Zoological Survey of India, Calicut (Reg. No. ZSI/WGRC/T42-45).

Influence of Weather Parameters

In order to assess the relationship between meteorological parameters and parasitoid population, data on minimum and maximum temperature (°C) forenoon and afternoon humidity (%), rainfall (mm) and sunshine (h) recorded at the meteorological observatory were correlated with per cent parasitization using Spearman's rank correlation [18]. *T. cuspis* prediction equation was derived through multiple regression analysis with polled data of meteorological parameters for all 3 years with respect to the per cent parasitism [19].

Biology

Attempts were made to breed the predominant parasitoid, *T. cuspis* on *H. antonii*. For this purpose fresh *H. antonii* eggs laid on tender cashew shoots fixed in glass vial (5 ml) with wet absorbent cotton were exposed to females. A total of 150 eggs of <24 h age were offered to *T. cuspis*. Males are similar to females differing only in shape of metasomal tip and antennal characters [20]. The time taken for the emergence of adult *T. cuspis* from the laboratory parasitized *H. antonii* eggs (n = 106) was recorded as development time. Sex ratio was estimated from successfully emerged individuals. The longevity of adult *T. cuspis* emerged in the laboratory was determined in glass tubes (25 × 200 mm length) by providing 10 % honey solution in the form of minute droplets.

Behaviour

Ten 2–3 days old *T. cuspis* females were allowed to mate with males in plastic container (250 ml capacity). Females were kept individually in the glass beaker (22 × 11 cm), with a wet muslin cloth sleeve. From the moment the female first showed symptoms for the egg laying, her behaviour was observed for 2 h with the help of magnifier metal hand lens (10×) and stereomicroscope. The distinct kinds of behaviour and their durations were observed and recorded in the process of oviposition.

Results and Discussion

A total of 8037 eggs of *Helopeltis* were sampled and reared during the present study. Three species of egg parasitoids viz., *T. cuspis* Rajmohana and Srikumar (Hymenoptera: Platygastridae), *Chaetostricha* sp. (Hymenoptera: Trichogrammatidae) and *Erthymelus helopeltidis* Gahan (Hymenoptera: Mymaridae) emerged from *Helopeltis* spp. eggs (Online resource 1-3). *T. cuspis* was the most abundant species with 6.32 % of mean parasitism rate (ranging from 0 to 28.21 %), whereas *Chaetostricha* sp. and *E. helopeltidis* showed relatively low level of parasitism of 0.30 and 0.16 % (ranging from 0 to 2.22% and from 0 to 2.25 %, respectively) (Table 1). The study was similar to that of Manja Naik and Chakravarthy [14] who also reported *Telenomus* sp. as predominant egg parasitoid of *H. antonii* in Brahmavar, Pethri and Chintamani cashew plantations of Karnataka.

The seasonal per cent parasitism indicated that *T. cuspis* occurred almost throughout the year and acted as major mortality factor of *H. antonii*. It extended the parasitization during the cropping period. However, *T. cuspis* disappeared during March and April (peak summer period) showing significant negative correlation ($P < 0.05$) with maximum temperature (Table 2). The maximum parasitism rate during June and July (peak monsoon period) ranged from 6.89 to 28.21 %, showing significant positive correlation ($P < 0.05$) with rainfall. The afternoon humidity also exhibited significant positive correlation ($P < 0.05$) with *T. cuspis* parasitization. This gives an indication that decreased maximum temperature, increased rainfall and

Table 1 Parasitism rate (%) of the egg parasitoids of *Helopeltis antonii* from 2010 to 2013

Months	*H. antonii* eggs	*T. cuspis*	*Chaetostricha* sp.	*E. helopeltidis*
10-Jun	39	28.21	0.00	0.00
July	251	10.76	0.00	0.00
August	312	7.69	0.00	0.00
September	263	2.28	0.00	0.00
October	136	1.47	0.00	0.00
November	106	3.77	0.00	0.00
December	222	9.91	1.80	2.25
11-Jan	402	9.70	0.75	0.25
February	135	8.15	2.22	0.00
March	178	0.00	0.00	0.00
April	120	0.00	0.00	0.00
May	281	9.96	0.00	0.00
June	305	6.89	0.00	0.00
July	259	9.65	1.16	1.54
August	133	5.26	0.00	1.50
September	77	6.49	0.00	1.30
October	115	6.09	0.00	0.00
November	192	4.17	1.04	0.00
December	195	3.59	1.54	0.00
12-Jan	605	6.61	0.33	0.00
February	589	5.09	0.00	0.00
March	201	0.00	0.00	0.00
April	92	0.00	0.00	0.00
May	249	1.61	0.00	0.00
June	408	7.35	0.49	0.00
July	280	11.79	0.00	0.00
August	67	11.94	0.00	0.00
September	192	1.56	0.00	0.00
October	144	12.50	0.00	0.00
November	361	11.91	0.00	0.00
December	192	6.77	0.00	0.00
13-Jan	104	6.73	0.00	0.00
February	224	10.27	0.89	0.00
March	343	0.00	0.00	0.00
April	121	0.00	0.00	0.00
May	144	1.39	0.00	0.00
Total	8,037	6.32	0.30	0.16

Table 2 Correlation coefficients of egg parasitoids with meteorological parameters

Per cent parasitism	Temperature (°C)		Humidity (%)		Rainfall	Sunshine
	Max	Min	Forenoon	Afternoon	(mm)	(h)
T. cuspis	−0.39*	0.03	0.28	0.38*	0.35*	0.24
Chaetostricha sp.	0.11	−0.58**	−0.1	−0.18	−0.09	0.32*
E. helopeltidis	−0.22	−0.05	0.39*	0.26	0.30*	−0.23

* 5 % level; ** 1 % level

afternoon humidity may be the promoting activities of *T. cuspis* on cashew.

The occurrence of *Chaetostricha* sp. and *E. helopeltidis* was occasional and mostly restricted to the cropping season (December-March) with a maximum parasitism rate of 2.22 and 2.25 %, respectively. *Chaetostricha* sp. showed significant negative correlation ($P < 0.01$) with minimum temperature and *E. helopeltidis* showed significant positive correlation ($P < 0.05$) with forenoon humidity.

The prediction equation based on the polled meteorological parameter data for 3 years and *T. cuspis* parasitism is as follows:

$$Y = 127.84 + 0.15X_1 - 0.12X_2 - 1.92X_3 + 0.66X_4 + 2.57X_5 - 0.01X_6$$

where, Y = Predicted *T. cuspis* parasitism; X_1 = Maximum temperature; X_2 = Minimum temperature; X_3 = Humidity forenoon; X_4 = Humidity afternoon; X_5 = Rainfall and X_6 = Sunshine hours.

The R^2 value obtained when subjected to multiple regression analysis was 0.38. This low R^2 indicates that the dependence of parasitoids remained unexplained in the light of the abiotic factors when taken together. It means that some other factors have also considerable influence on parasitoid population. Parasitoids are likely to experience low population densities, either because of their interactions with host, chemical pest control and demographic Allee effect (decreasing per capita population growth rates when abundance declines) as proved by Bombard [21].

The parasitoid population fluctuation in relation to temperature and humidity is shown in Fig. 1 and in relation to rainfall and sunshine hours in Fig. 2. The parasitoid population was higher from December to February, which was synchronized with the higher number of host eggs observed during the same period.

Five different kinds of *T. cuspis* female behaviours were observed as drumming, ovipositor insertion, marking, walking and resting. Drumming was characterized by movement of antennae up and down over the exposed surface of the eggs, the female remained still or walked over the eggs. During drumming, the females did not follow a definite direction, returning to the same egg many times. Subsequently, the female paused so that the egg was behind her, inclined her body and inserted the ovipositor in the host egg when drumming stopped. From this moment on, she remained still, with no antennae movement and directed towards base, wings parallel to the body and hind legs firmly holding the extrachorionic process of host egg (Fig. 3). After the ovipositor was retreated, the female moved backwards, the posterior region of her abdomen swinging laterally, 'brushing' along the surface of the egg, and evidencing a marking behaviour. Walking was characteristic of the lack of interest for the eggs by the female. She walked on top of the egg without drumming. The average time spent was

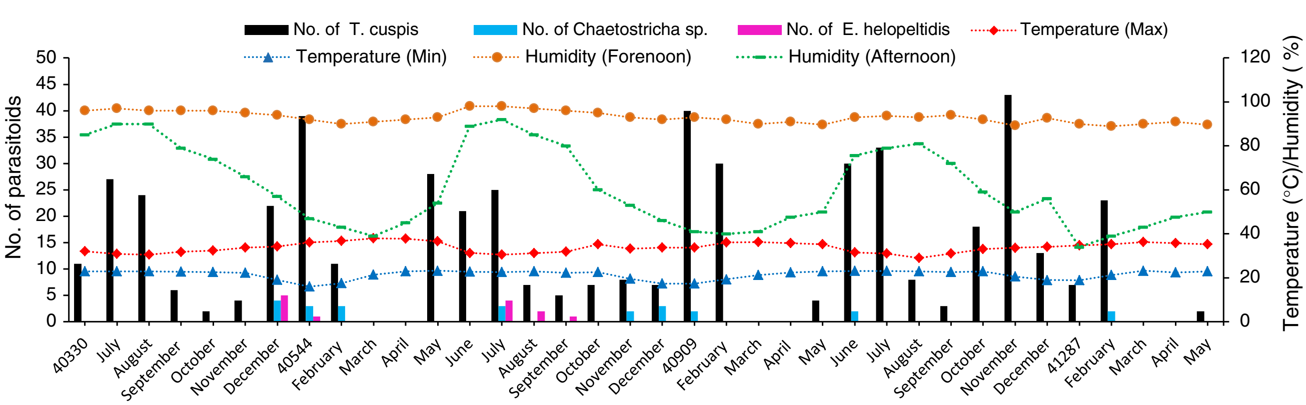

Fig. 1 Fluctuation of parasitoids population, air temperature and humidity

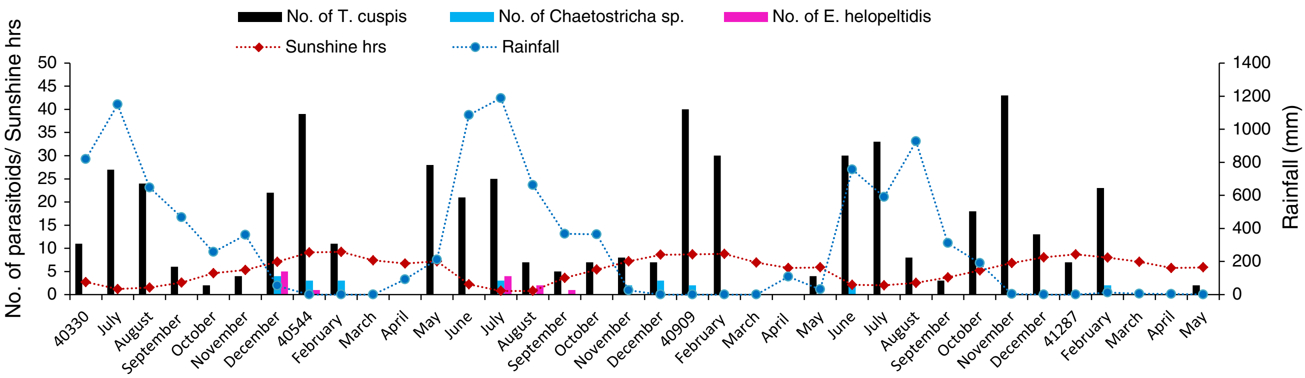

Fig. 2 Fluctuation of parasitoids population, rainfall and sunshine

Fig. 3 *Telenomus cuspis* parasitizing *H. antonii* egg

4.25 ± 0.45 min for drumming, 17.63 ± 2.49 min for ovipositor insertion and 0.95 ± 0.25 min for marking i.e. the mean time spent on parasitization was 22.83 ± 2.24 min per egg (n = 102). The behaviour observed for *T.* cuspis females (drumming, ovipositor insertion, marking, walking and resting) are common to many species in the Platygastridae family, for example, *Gryon gallardoi* [22], *Telenomus nakagawai* Watanabe [23], *T. sphingis* Ashmead [24], *T. heliothidis* Ashmead [25] and *T. triptus* Nixon [26]. The time spent on each kind of behaviour by *T. cuspis* sp. was more than that of *Gryon gallardoi* [22].

On dissection, *T. cuspis* parasitized eggs showed initially dark colouration progressing from proximal end to distal end of the egg while unparasitized eggs were reddish with advanced embryonic growth (Fig. 4). Immature developmental period of *T. cuspis* was 20.6 ± 1.13 days with the range of 18–30 days. Sex ratio was found to be female biased (1:0.85) (n = 106), and the longevity was 4.52 ± 0.11 (female) and 2.83 ± 0.16 days (male) (n = 106).

Telenomus cuspis had shown prolonged developmental period in host eggs (30 days), whereas unparasitised host eggs hatched within 6–10 days [27] (Online resource 4 & 5). Such phenomenon of prolonged developmental period of parasitoid over host insect is a well-adapted host-parasite relationship. This might ensure the continued availability of hosts and thus, the survival of the parasitoids [28]. At the same time when the pest density has reached a certain high level, it is unlikely that its equilibrium

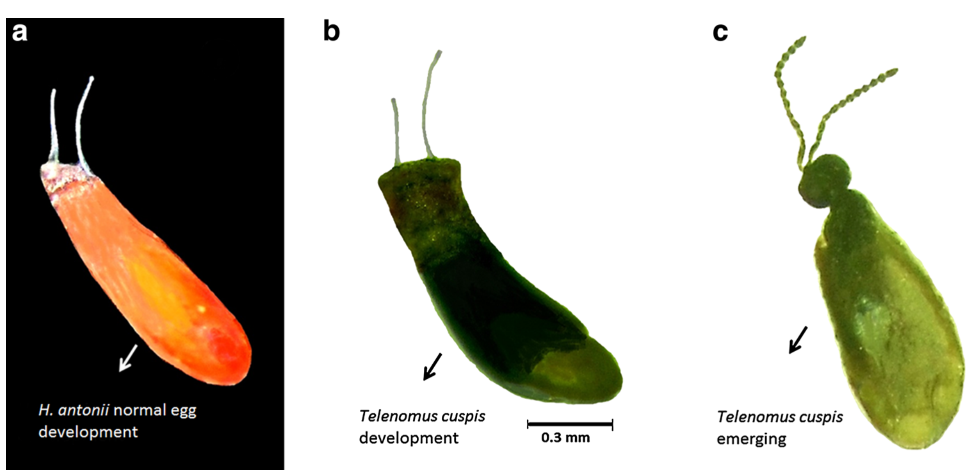

Fig. 4 **a** *Helopeltis antonii* healthy, unparasitized egg, **b** *H. antonii* parasitized egg and **c** *T. cuspis* emergence from parasitized host egg

population size can be lowered by egg parasitoid activity alone [29].

Conclusion

Egg parasitoids of *H. antonii,* particularly *T. cuspis* have shown some potential in reducing the host population in cashew. As suggested by Bin [30] the establishment of parasitoid population depends upon proper conservation and enhancement techniques. The results on population dynamics of parasitoids as well as biology and behaviour of *T. cuspis* may hold a key role in the biological control studies of *H. antonii* on cashew.

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