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Mites (Acari) associated with *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) in Malaysia, with a revised list of the mites found on this weevil

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ABSTRACT

There is a great deal of diversity among phoretic association particularly in mesostigmatic mites that exploited insect host to complete their dispersal strategy. Similarly, the red palm weevil, *Rhynchophorus ferrugineus*, also has been used as a carrier by the phoretic mites. In this study, we found *Centrouropoda almerodai* (Uropodidae), *Macrocheles mammifer*, *Macrocheles* cf. *oigru* (Macrochelidae), *Uroobovella assamomarginata* and *Uroobovella javae* (Dinychidae) as the phoretic mites associated with the Malaysian red palm weevils. Male weevils had significantly greater number of mites per host as compared to the female weevils. Present study revealed that the red palm weevils were infested with very large numbers of phoretic mites which occur mainly under the elytra. Our results combined with those in the literatures suggest the potential role of phoresy in the evolution of parasitism.

Introduction

The red palm weevil, *Rhynchophorus ferrugineus* Olivier, 1790 is an important pest of palm trees in Asia, which has been reported from 19 Asian countries (Murphy and Briscoe, 1999). In the recent years, this weevil has been assumed to be a serious pest in all major coconut growing tracks of Malaysia, as it is found throughout the year and causes great yield losses. Among the known palm pests, it is the most harmful because the infestations are often not detected until the fronds wilt and the crown collapses suddenly by which time the tree is beyond recovery (Sivapragasam et al., 2010). The late detection of red palm weevil infestations constitutes a serious problem in the fight against this lethal pest of coconut palms.

The biology of red palm weevil has been studied in many countries including India, Indonesia, Myanmar, Philippines, Iran and Spain (Avand-Faghih, 1996; Esteban-Duran et al., 1998; Murphy and Briscoe, 1999). Red palm weevil has been reported to be associated with numerous types of arthropods, including mites and parasitic insects and even microorganisms such as viruses, bacteria, fungi and nematodes (Murphy and Briscoe, 1999). The symbiotic relationship between some of these species could have positive, neutral or negative influences on the weevil, and the most least studied of which are the mites (Acari). Mites are known to be phoretic associated with red palm weevil and their relationships have been described by several authors (Al-Deeb et al., 2011; Hassan et al., 2011; Mazza et al., 2011). Phoresy is a phenomenon by which an organism (phoront) is actively carried on or in another organism (host) for a limited time period to complete their dispersal strategy to favourable habitats (OConnor, 1982; Kaliszewski et al., 1995).

To date, the identity and type of interaction of phoretic mites on the red palm weevil has not been studied in Malaysia. In fact, this is the second research on phoretic mites–insect interaction followed by the first study conducted by Ho (1990) on phoretic association between *Macrocheles muscaedomesticae* Scopoli, 1772 (Macrochelidae) and flies in Malaysia. This study was carried out to report the mite species associated with the red palm weevil and to determine the distribution patterns of mites on the weevil's body. Besides, the prospective consequences of phoretic mites on the red palm weevils have also been discussed in this paper.

Materials and methods

Sample collection

From November 2012 to March 2013, 150 live adults of the red palm weevil, *Rhynchophorus ferrugineus*, (sex ratio = 1:1) were collected by hand from infested coconut farms at Terengganu

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(5° 33′ N, 103° 15′ E) and Kelantan (6° 13′ N, 102° 14′ E), Malaysia. Captured weevils were transported back to the laboratory and were stored in a freezer at −20 °C.

Mite identification and distribution pattern

Weevils were dissected individually under a stereomicroscope and the number of mite presence on the head, thorax, abdomen, elytra, membrane wings and legs were counted. Mites were separated from the weevils using a camel hair brush and preserved in 70% ethanol. These mites were then cleared and mounted in Hoyer's medium on permanent microscopic slides for identification under a microscope at 40–400× magnification. The mite species were identified with the help of the original descriptive papers (original descriptions and illustrations) in which these species were firstly described. Specimens of mite taxa identified in this study were deposited in the Entomology Laboratory of Station MARDI Bachok, Malaysia.

Statistical analysis

Statistical analysis was carried out using SPSS version 15.0. All data were found to be non-normally distributed and were therefore analysed via nonparametric methods. Host preference of phoretic mites either on male or female red palm weevils was compared using Mann–Whitney *U* test ($p \leq 0.05$). Kruskal–Wallis test was performed to analyse the distribution of mites on different body regions of the weevils ($p \leq 0.05$). The Student–Newman–Keuls method was further used for pairwise multiple comparisons ($p \leq 0.05$).

Results

Five phoretic species from three different families of Mesostigmata are documented for the first time as associates of the red palm weevil in Malaysia, namely *Centrouropoda almerodai* Hiramatsu and Hirschman, 1992 (Uropodidae), *Macrocheles mammifer* Berlese, 1918, *Macrocheles* cf. *oigru* Walter and Krantz, 1986 (Macrochelidae), *Uroobovella assamomarginata* Hiramatsu and Hirschman, 1979 and *Uroobovella javae* Wiśniewski, 1981 (Dinychidae) (Fig. 1). The present study has shown that, mites were phoretically attached to all tested red palm weevils ($n = 150$). Phoretic load ranged from 11–838 and 42–1345 individuals per host on female and male red palm weevils, respectively (Fig. 2). Mean abundance of phoretic mites on male weevils was significantly higher than that on female weevils ($p = 0.004$). Kruskal–Wallis analysis showed that the mite loads were significantly different among the body regions of the weevil ($p \leq 0.001$) (Fig. 3). The mean distributions of phoretic mites on the inner elytral surface for both sexes were significantly greater than those observed in the other body regions ($p \leq 0.05$). The second highest phoretic load was observed in the membrane wing followed by the abdomen. However there is no significant difference between these two body regions. Meanwhile the lowest phoretic loads were observed in the head followed by the leg and thorax.

Discussion

Among the identified taxa of mites in Table 1, there are 25 species and 21 genera in 18 families and two superorders (Parasitiformes and Acariformes) reported in association with *R. ferrugineus*. The high

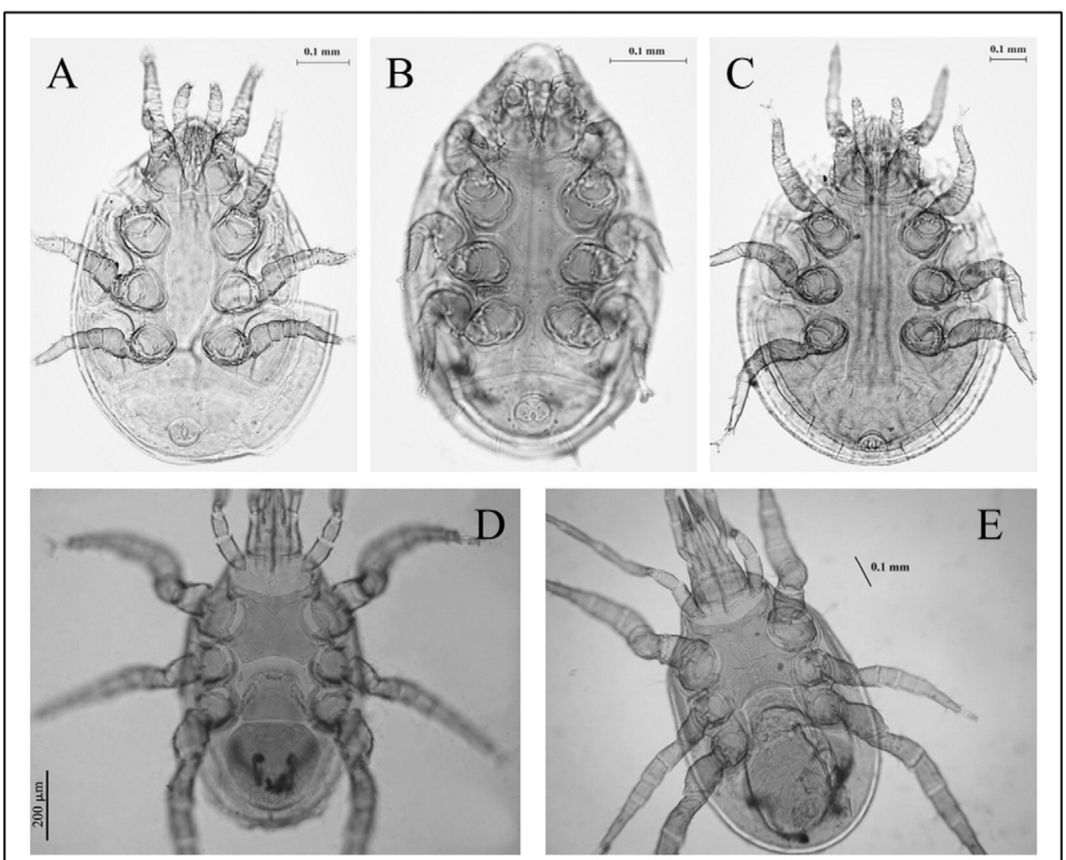

Fig. 1. Mesostigmatic mites found on *Rhynchophorus ferrugineus* in Malaysia: *Centrouropoda almerodai* (A), *Uroobovella javae* (B), *Uroobovella assamomarginata* (C), *Macrocheles* cf. *oigru* (D) and *Macrocheles mammifer* (E).

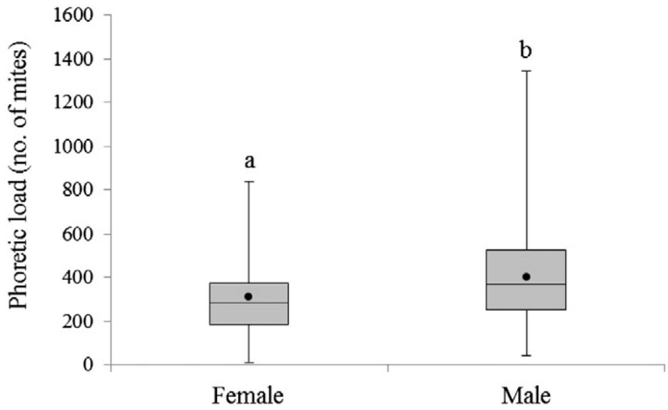

Fig. 2. Host preference of mesostigmatic mites on female and male *Rhynchophorus ferrugineus*. In the box plots, horizontal lines indicate the medians, circles indicate the means, and lower and upper boundaries of the boxes indicate the 25 and 75% quartiles, respectively and whiskers below and above the boxes indicate the minimum and maximum values of the group, respectively. Means were separated using Mann–Whitney *U* test ($p \leq 0.05$).

level of phenotypic similarity in some groups of mites makes species identification difficult, and has led to many misinterpretations and misidentifications. Based on available photos in some papers (El Beshlawy and Allam, 2007; Mesbah et al., 2008; El-Sharabasy, 2010; Al-Deeb et al., 2011; Al-Dhafar and Al-Qahtani, 2012), we could detect some of these misidentifications and they are integrated into Table 1. The Mesostigmata was the most diverse group, with a total of 21 identified species (84%), followed by Trombidiformes and Sarcoptiformes, with three and one species, respectively. Mites of the red palm weevil have been reported from 16 countries (Table 1), of which most of the known species have been reported from Egypt (14). Out of five phoretic mite species found in this study, three are recorded for the first time to have phoretic associations with the *R. ferrugineus*, namely *M.* cf. *oigru*, *M. mammifer* and *U. assamomarginata*. On the other hand, the mites *C. almerodai* and *U. javae* have already known to be associated with the *R. ferrugineus* (Wiśniewski, 1981; Longo and Ragusa, 2006; Porcelli et al., 2009; Ragusa et al., 2009a, 2009b; Mazza et al., 2011), while *M. mammifer* (incorrectly published under the name *Glyptholaspis* sp.) with other congeneric host species, the South American palm weevil, *R. palmarum* Linnaeus, 1758 (Rodríguez-Morell et al., 2012).

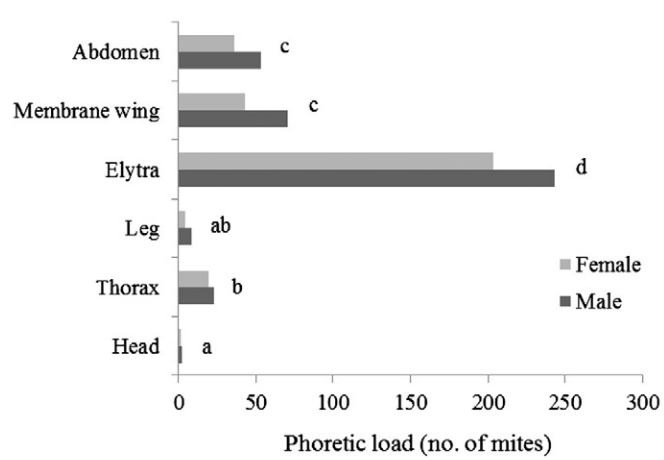

Fig. 3. Distribution of mesostigmatic mites on different regions of male and female *Rhynchophorus ferrugineus*. Means of unsexed weevils across body regions followed by similar letters have no significant differences after analysed by Student–Newman–Keuls test ($p \leq 0.05$).

Table 1
Mites (Acari) associated with *Rhynchophorus ferrugineus* reported from present* and previous studies.

Mite species	Location	Reference
Parasitiformes, Mesostigmata, Sejida		
Sejina: Sejidae		
Sejus baloghi (Athias-Henriot)	Egypt	Hassan et al. (2011)
Sejus sp.	Saudi Arabia	Al-Dhafar and Al-Qahtani (2012)
Trigynaspida		
Antennophorina: Diplogyniidae		
Schizodiplogynium sp.	India	Peter (1989)
Uropodina		
Uropodina sp.	Egypt	El-Sharabasy (2010)[1]
Dinychidae		
Uroobovella assamomarginata Hiramatsu and Hirschmann	Malaysia*	
Uroobovella javae Wiśniewski	Indonesia	Wiśniewski (1981)
	Malaysia*	
Uroobovella krantzi Zaher and Afifi	Egypt	Gomaa (2006)
Uroobovella marginata C. L. Koch	Egypt	Mesbah et al. (2008)[2]
	Turkey	Atakan et al. (2009)
	Malta	Porcelli et al. (2009)
	Italy	Ragusa et al. (2009a)
	Egypt	El-Sharabasy (2010)[3]
		Hassan et al. (2011)[4]
	Emirates	Al-Deeb et al. (2011)[5]
Uroobovella sp.	India	Peter (1989)
Trematuridae		
Nenteria javae Wiśniewski and Hirschmann	Indonesia	Wiśniewski and Hirschmann (1981)
Trichouropoda sp.	Egypt	Hassan et al. (2011)[6]
	Saudi Arabia	Al-Saqabi (2012)
Uropodidae		
Aegyptus alhassa Al-Dhafar and Al-Qahtani	Saudi Arabia	Al-Dhafar and Al-Qahtani (2012)[7]
Aegyptus rhynchophorus El-Beshlawy and Allam	Egypt	El Beshlawy and Allam (2007)[7]
	Egypt	Allam and El-Bishlawi (2010)
	Egypt	Hassan et al. (2011)
	Egypt	Allam et al. (2013)
Aegyptus zaheri Abdel-Ghany	Egypt	Abdel-Ghany (2009)
		Hassan et al. (2011)
Centrouropoda almerodai Hiramatsu and Hirschmann	Philippines	Wisniewski et al. (1992)
	Italy	Longo and Ragusa (2006)
	Egypt	Mesbah et al. (2008)[8]
	Italy	Longo et al. (2009)
	Malta	Porcelli et al. (2009)
	Italy	Ragusa et al. (2009a)
	Italy	Ragusa et al. (2009b)
	Emirates	Al-Deeb et al. (2011)[9]
	Italy	Mazza et al. (2011)
	Malaysia*	
Uropoda orbicularis (J. Müller)	Turkey	Atakan et al. (2009)
Uropoda sp.	Saudi Arabia	Al-Saqabi (2009)
Gamasina: Ascidae		
Ascidae sp.	Iran	Avand-Faghih (1996)
Protogamasellus denticus Nasr	Egypt	Hassan et al. (2011)
Digamasellidae		
Dendrolaelaps aberratus Hirschmann and Wiśniewski	Ecuador	Hoppe and Stützel (2013a)[10]
Dendrolaelaps australicornutus Hirschmann	Brazil	Hoppe and Stützel (2013b)[10]
Dendrolaelaps sp.	Egypt	Hassan et al. (2011)
Digamasellus sp.	Egypt	Hassan et al. (2011)
Laelapidae		
Cosmolaelaps keni	Egypt	Hassan et al. (2011)
Hypoaspis queenslandicus (Womersley)	Egypt	Gomaa (2006)
Hypoaspis sp.	India	Peter (1989)
	Egypt	El-Sharabasy (2010)[11]
Macrochelidae		
Macrocheles mammifer Berlese	Malaysia*	
Macrocheles merdarius (Berlese)	Egypt	Hassan et al. (2011)
Macrocheles cf. *oigru* Walter and Krantz	Malaysia*	
Macrocheles sp.	Egypt	Hassan et al. (2011)

(continued on next page)

Table 1 (*continued*)

Mite species	Location	Reference
Melicharidae		
Proctolaelaps striatus (Westerboer)	Egypt	Hassan et al. (2011)[12]
Parasitidae		
Parasitus zaheri Hafez and Nasr	Egypt	El-Sharabasy (2010)
Acariformes, Trombidiformes, Prostigmata		
Heterostigmatina: Scutacaridae		
Scutacarus sp.	Egypt	El-Sharabasy (2010)
Raphignathina: Cheyletidae		
Eutogenes punctatus Zaher and Soliman	Egypt	Gomaa (2006)
Podapolipidae		
Rhynchopolipus rhynchophori (Ewing)	Saudi Arabia	Abdullah (2009)
Rhynchopolipus swiftae Husband and OConnor	Indonesia	Husband and OConnor (1999)
	China	Husband (pers. comm.)
	Papua New Guinea	Husband (pers. comm.)
	Thailand	Husband (pers. comm.)
Sarcoptiformes		
Oribatida: Galumnidae		
Galumnidae sp.	Egypt	Hassan et al. (2011)
Oppiidae		
Multioppia wilsoni Aoki	Egypt	Hassan et al. (2011)
Astigmata: Acaridae		
Acaridae sp.	Egypt	El-Sharabasy (2010)[13]
	Saudi Arabia	Al-Dhafar and Al-Qahtani (2012)
Histiostomatidae		
Curculanoetus sp.	Emirates	Al-Deeb et al. (2011)

[1] Published as *Trichouropoda patavina* (G. Canestrini).
[2] Published as *Leiodinychus krameri* (G. Canestrini).
[3] Published as *Iphidosoma* sp.
[4] Published as *Fuscuropoda marginata* (C. L. Koch).
[5] Published as *Uropoda orbicularis* (Müller).
[6] Published as *Oodinychus* sp.
[7] Assumedly a synonym of *Centrouropoda almerodai*.
[8] Published as two different species: *Uroobovella varians* Hirschmann and Zirngiebl-Nicol, and *Pachylaelaps spectabilis* Berlese.
[9] Published as *Uroobovella* sp.
[10] Host identity uncertain.
[11] Published as *Hypoaspis sardoa* (Berlese).
[12] A synonym of *Proctolaelaps bickleyi* (Bram) as accepted by some authors.
[13] Published as *Histiostoma* sp.

The experimental evidence has shown that the presence of *C. almerodai* causes the distraction in the weevil's health status by reducing the life span of the infested weevil becoming 1.4-times shorter than the non-infested weevils (Mazza et al., 2011). Moreover, there is also a report where phoretic mites from Uropodidae acquired haemolymph from the ant *Pheidole megacephala* Fabricius, 1793 and caused conspicuous morphological change and death to the host (Breton et al., 2006). Besides, we also found two species of *Macrocheles* mites settling on the weevil body, where mites of this genus have been reported as the predators on larvae and eggs of houseflies (Ito, 1977). On the other hand, there are few numbers of cases that documented the phoresy relationship of *Uroobovella* mites with the red palm weevils (Atakan et al., 2009; Porcelli et al., 2009; Al-Deeb et al., 2011). Interactions of *Uroobovella* mites with other insects also have been reported in previous studies with less information about their effects on the respective host (Athias-Binche et al., 1993; Masan, 2001; Bloszyk et al., 2006; Pernek et al., 2012).

In the present study, the numbers of mites on the male weevils were higher than those on the female weevils which revealed the preference of mites for male weevils during phoresy. This finding is in line with the results of previous study which have demonstrated that male biased association of phoretic mites on insect occurs in some species of beetles (Grossman and Smith, 2008; Al-Deeb et al., 2012). Selection of male over female could be due to size; male are larger and alternatively provide more space for attachment of mites. Besides, phoretic mites also benefit from larger weevil as they can protect and defend carcass. A morphological study conducted on the Malaysian red palm weevil has showed that the mean body length and width of male weevils were slightly higher than the female weevils, which ranged from 25.01 mm/11.01 mm (length/width) for males and 24.68 mm/10.67 mm for females (Wahizatul et al., 2012). Although it seems that the differences of body length or width for male and female weevils were roughly marginal, this factor may contribute to the male-biased association.

Abundant studies have shown that some mite species were captivated by the semiochemical and influence their host selection (Schwarz and Koulianos, 1998; Niogret et al., 2006; Amin et al., 2009). In this case, we suspect that the response of mites towards emitted kairomone might cause the male weevils to be infested heavily as compared to the female weevils. Niogret et al. (2006) found that *Macrocheles saceri* Costa, 1967 utilizes the kairomone released by the dung beetle as a mediator to find the location of the host. Similarly, the predator mite *Phytoseiulus macropilis* Banks, 1904 benefits the kairomone produced by their rearing host *Tetranychus urticae* Koch, 1836 to find the potential prey (Amin et al., 2009). It is known that the male red palm weevil produces pheromone to attract individual from the same species (Oehlschlager et al., 1995), but there is no research evidence on kairomonal role play by the red palm weevil. Therefore, further study is needed to determine the effects of kairomone released by the red palm weevil on the behaviour or preference of phoretic mites.

The distribution of phoretic mites were found varied on the red palm weevil body regions. The maximum load of phoretic mites was found on the inner surface of the elytra. Similarly, this result is in agreement with the past work done by Al-Deeb et al. (2011) who highlighted the greatest number of mites located on the elytra of the red palm weevil. This is likely because mites under the elytra were protected from hot environment and less desiccated. Moreover, the subelytral cavity seems to be safer to the mites especially when the weevil walks through palm trees and dense fibres. In addition, mites hitching beneath the elytra probably possess lower possibilities to fall since the elytra are not used actively in flight compared to the membrane wings (Al-Deeb et al., 2011). It is likely that mites discriminately choose any body regions that could hide and provide protection against unfavourable condition once the elytra space was fully occupied.

Although the function of phoresy is dispersal, it actually might lead to deleterious effect on the host. Bajerlein and Bloszyk (2004) have reported that such condition may take place when mites are present in very high densities with more than 100 individuals per host. Interestingly, the present study has revealed that the red palm weevils were infested heavily by the mites where up to 1345 individuals per host. This result leads us to believe that phoretic mite could impose a cost for the host. The presence of thousands of mites on the weevil's body can reduce the efficiency of foraging activities and making the weevils more susceptible to predation (Al-Deeb et al., 2011). High abundance of mites also negatively affects host activities like flying and movements and even results in exhaustion or death to the host (Bajerlein and Bloszyk, 2004).

From previous study, there are many reported cases that showed that the phoretic mites act as parasites to their respective hosts (Houck and Cohen, 1995; Cardoza et al., 2008; Al-Deeb et al., 2011; Mazza et al., 2011). This increases our concern that phoretic mites and red palm weevil association is not merely phoretic as the mites may possibly prey on weevil's larvae and exploit their protein source (Mazza et al., 2011). However, more detail studies are needed to investigate the evolution of this relationship by physically and biologically. This area will be a fertile ground for researchers to understand the real impact of phoretic mites towards the life cycle of the weevil. Moreover, phoretic mites could be an alternative bio-control agent if there is a proven data by field studies on its antagonistic behaviour against the weevil.

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