DISTRIBUTION AND ABUNDANCE OF PHORETIC MITES (ASTIGMATA, MESOSTIGMATA) ON RHYNCHOPHORUS FERRUGINEUS (COLEOPTERA: CURCULIONIDAE)

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ABSTRACT

The red palm weevil, Rhynchophorus ferrugineus Olivier, is the most important insect pest on date palms. Weevils were collected from randomly selected infested date palms in Al Ain, United Arab Emirates (UAE). Mites from three families were recorded. Uroobovella sp. (Acari: Urodinychidae) were the most common phoretic mites. Curculanoetus sp. (Acari: Histiostomatidae) were second in abundance. Uropoda orbicularis (Acari: Uropodidae) was recorded on one beetle. The abundance of phoretic mites varied among body parts of R. ferrugineus, and the maximum numbers occurred in the subelytral space. The mean intensity, mean abundance, and prevalence of Uroobovella and Curculanoetus mites did not differ between male and female weevils. Uroobovella had significantly greater mean intensity, abundance and prevalence compared to Curculanoetus. Most Uroobovella and Curculanoetus aggregated under the subelytral space, which presumably offers protection from the hot and dry environment. This study is the first to document the presence of phoretic mites on R. ferrugineus in UAE and will help to direct future research on their interactions.

Key Words: Rhynchophorus ferrugineus, Red palm weevil, Uropoda orbicularis, Uroobovella, Curculanoetus, phoresy

RESUMEN

El picudo rojo de la palma, Rhynchophorus ferrugineus Olivier, es el insecto plaga más importante de la palmera de dátiles. Picudos fueron colectados de palmas de dátiles infestadas seleccionadas al azar en Al Ain, Emiratos Arabes Unidos (EAU). Ácaros de tres familias fueron encontrados. Los ácaros foréticos más comunes fueron Uroobovella sp. (Acari: Urodinychidae). Curculanoetus sp. (Acari: Histiostomatidae) fueron segundos en orden de abundancia. Uropoda orbicularis (Acari: Uropodidae) se encontró en solo un picudo. La abundancia de ácaros foréticos en las diferentes partes del cuerpo de R. ferrugineus fue variable, los números más altos se encontraron el espacio subelítrico. La intensidad promedio, abundancia promedio, y prevalencia de los ácaros Uroobovella y Curculanoetus no fue diferente entre picudos macho o hembra. Uroobovella tuvo una mayor intensidad promedio, abundancia y prevalencia que Curculanoetus. La mayoría de Uroobovella y Curculanoetus se agregaron en el espacio subelítrico, el cual presumiblemente ofrece protección de un ambiente caliente y seco. Este es el primer estudio que documenta la presencia de ácaros foréticos sobre R. ferrugineus en los EAU y servirá para direccionar futuras investigaciones sobre sus interacciones.

The red palm weevil (Rhynchophorus ferrugineus Olivier) is a pest of a broad range of palms (Palmae) in southern Asia (Murphy & Briscoe 1999). In the 1980s, the species expanded its range and invaded into the Middle East, North Africa (Abraham et al. 1998; Murphy & Briscoe 1999), and more recently into Western Europe (Conti et al. 2008). Rhynchophorus ferrugineus was first detected in the United Arab Emirates (UAE) in 1986 and has since been an important cause of decline in date production (Abraham et al. 1998). The date palm (Phoenix dactylifera L.) is the most com-
monly cultivated plant in the Middle East and North Africa, with hundreds of thousands of tons of dates being produced annually; amounting to millions of dollars worth of dates (Murphy & Briscoe 1999). Consequently, R. ferrugineus represents a major threat to the industry.

The biology of R. ferrugineus has been studied in great detail in India on several palm species including date palms (Murphy & Briscoe 1999). Generally, R. ferrugineus assemble on damaged parts (and sometimes undamaged parts) of date palms. Larvae burrow through the soft tissue of the crown or the base of petioles forming extensive tunnels. In severely infested trees, these tunnels may cause the crown and trunk to weaken and eventually break, resulting in death of the tree. The larva develops in a cocoon and eventually emerges as an adult weevil (Abraham et al. 1996; Murphy & Briscoe 1999).

A number of species have been recorded as natural enemies of R. ferrugineus including viruses, bacteria, fungi, nematodes, insects and mites (Murphy & Briscoe 1999). However, limited information exists on the extent to which these species affect R. ferrugineus populations. The relationship between some of these species and R. ferrugineus ranges from phoretic to parasitic. Phoresy is a complex symbiotic association that has evolved in many organisms as a result of spatial and temporal isolation of their habitats (O’Connor 1982). It is defined as a form of commensalism facilitating the physical transport of one organism on the body of another, during which time no feeding or reproduction occurs in the phoretic organism (Binns 1982; O’Connor 1982). Although the term host is generally associated with parasitism, we use the term host to describe carriers of phoretics as well as hosts of parasites, following O’Connor (1982), Houck & O’Connor (1991) and Houck & Cohen (1995). In the Astigmata, only one of the life stages, the deutonymph (sometimes termed a hypopus), exhibits phoretic behavior. The hypopi have evolved morphological adaptations, such as attachment devices, to aid in phoresy. Phoretic associations are particularly diverse in astigmatid (Acari: Astigmata) and mesostigmatid mites (Acari: Mesostigmata) that have exploited many vertebrate and invertebrate hosts for movement between suitable habitats. Phoresy in the cohort Uropodina (Acari: Mesostigmata) also occurs in the deutonymphs although some species may not develop phoresy in certain habitats (O’Connor 1982; Houck & O’Connor 1991).

Although the primary function of phoresy is dispersal, phoretic associations may be complex (Binns 1982; O’Connor 1982; Houck & O’Connor 1991). Some apparently phoretic mites, for example, may use the association not only for dispersal, but in some examples may even derive nutrition from their host. The hypopi of the *Hemise-
Hypoaspis (Acari: Laelapidae) consists of a group of predatory mites which are found associated with many beetles, especially those in the family Scarabaeidae (Costa 1971). Mites in this genus have occasionally been observed eating eggs and larvae of scarabaeid beetles. Hypoaspis sp. and Tetrapolypus rhynchophori (Acari: Pyemotidae) have been found in association with R. ferrugineus (Peter 1989). Tetrapolypus rhynchophori are reported to be predators of R. ferrugineus (Lever 1969), but the frequency and extent to which these mites affect beetle populations remains unknown (Peter 1989). To date, there are no reports of phoretic organisms associated with R. ferrugineus in the UAE.

To this end, we examined the mites associated with R. ferrugineus collected from Al Ain, UAE. The objectives of this study were to i) determine the species composition and on-host distribution patterns of mites associated with R. ferrugineus; ii) examine patterns in the prevalence and abundance of mites on R. ferrugineus; and iii) discuss the nature of the association between the mites and their weevil hosts.

MATERIALS AND METHODS

Sample Collection and Preparation

Live adults and pupae (inside cocoons constructed from date palm tree fibers) of R. ferrugineus were collected from infested date palm plantations at Al-Ain (24° 11' N, 55° 45' E), UAE from Mar to Nov 2008 and 2009. Adults and pupae were individually collected by hand from infested trees and placed in plastic containers for transportation and were stored in a freezer at -20 °C in the laboratory. Twenty empty cocoons were placed in plastic containers and kept in an incubator 25 °C. Drops of distilled water were added every 2 days to maintain good moisture conditions. Containers were observed daily for 1 month.

For identification, mites were brushed off the weevils using a camel hair brush and stored in 70% ethanol until further processing. Mite specimens were cleared in lactophenol solution, mounted in Hoyer's medium on microscope slides (Krantz 1978; Evans 1992), and examined under a compound microscope. Scanning Electron Microscopy of selected specimens was done at the Central Laboratory Unit at UAE University. Uropoda orbicularis and Uroobovella sp. mites were identified by Durmus Ali Bal, Erzincan Education Faculty, Atatürk University, Erzincan, Turkey. Curculanoetus sp. mites were identified by Barry M. O’Connor, University of Michigan, USA. Mite samples were placed in the collection of the Biology Department of UAE University.

Quantification and Statistical Analysis

One hundred and five adult R. ferrugineus were collected from infested date palm trees. Individual R. ferrugineus were sexed and mites were counted on each weevil's head, thorax, legs, subelytral space, and abdomen under a dissecting microscope. The software Quantitative Parasitology 3.0, specifically developed to account for aggregated distributions and to allow distribution-free statistical tests, was used to compare loads (Reiczigel & Rózsa 2005). We quantified mean intensity (mean number of mites per weevil), mean abundance (mean number of mites per weevil) and prevalence (proportion of weevils that hosted mites) following Rózsa et al. (2000). Confidence intervals (at 95% confidence level) for mean intensities were computed using bootstrap techniques with 2000 replications (Rózsa et al. 2000). Exact confidence intervals (at 95% confidence level) were calculated for prevalence using the Clopper-Pearson method. Mean intensities and abundance of mites on male and female weevils were compared using bootstrap t-tests, and P-values were generated from 2000 replications (Rózsa et al. 2000). Prevalence of mites on males and females was compared using Fisher’s Exact Test, with the exact P-value reported. Differences in the mean intensity, mean abundance and prevalence of different mite species found on R. ferrugineus were also compared using the same methods. The Index of Discrepancy was calculated to determine aggregated distributions of mites on R. ferrugineus.

RESULTS

Deutonymphs of 2 mesostigmatid mite species, Uropoda orbicularis Müller (1776) and Uroobovella sp., were identified. Deutonymphs of U. orbicularis (Fig. 1) were encountered on 1 single young adult R. ferrugineus collected from a broken infested date palm trunk. The number of Uroobovella sp. deutonymphs (Fig. 2) on individual male and female weevils ranged from 0 to 381 and 0 to 598, respectively. Because the mean intensity (Bootstrap t-test, P >> 0.05), mean abundance (Bootstrap t-test, P >> 0.05), and prevalence (Fischer’s Exact test, P >> 0.05) of the mites on males and females did not differ significantly, the data were pooled (Table 1). Another phoretic mite of the genus Curculanoetus (Astigmata: Histiostomatidae) was recorded mostly in the subelytral space, but very rarely in other areas (Fig. 4 A, D, E).

The prevalence of Curculanoetus (17.1) was significantly lower than that of Uroobovella (63.8) (Fischer’s Exact test, P < 0.001). Similarly, the mean abundance (3.6) and mean intensity (21.2) of Curculanoetus was significantly lower than the mean abundance (40.2) and mean intensity (62.9)
of Uroobovella (Bootstrap t-test, $P = 0.006$ and $P = 0.01$, respectively). Index of Discrepancy values for Curculanoetus and Uroobovella were 0.929 and 0.802, respectively. Mite loads on different regions of the weevil also varied substantially (Fig. 3), with the greatest number of mites located in the subelytra in both sexes (Fig. 4 B, C). The membrane wings also had large numbers of mites, while the remaining regions of the weevil harbored few mites in both sexes. Curculanoetus and Uroobovella mites were not recovered from the heads of weevils.

Uroobovella deutonymphs were not always phoretic on $R$. ferrugineus adults (i.e. attached with anal pedicels to the weevil body for transportation). They were present in very large numbers on some pupae inside the cocoons (500-800/cocoon) and were noticed actively moving on the pupal exuvia.

In addition to uropodid mites Collembolla were observed on the fibers of the $R$. ferrugineus cocoons, which were incubated at 25 °C. The numbers of these microarthropods increased considerably with increasing stages of fiber decay.

**Fig. 1.** Uropoda orbicularis deutonymph, (A) SEM dorsal view; (B) SEM ventral view showing anal pedicel; (C) under light microscope ($\times$100); (D) deutonymphs aggregated on $R$. ferrugineus head and thorax.

**DISCUSSION**

Deutonymph stages of 3 mite species ($U$. orbicularis, Uroobovella sp. and Curculanoetus sp.) were associated with $R$. ferrugineus. Uropoda orbicularis and Uroobovella sp. were attached to their weevil hosts with the aid of anal pedicels, consistent with other studies (Bajerlein & Bloszyk 2004). In contrast, Curculanoetus sp. uses sucker plates for attachment to the weevil hosts. Not all $R$. ferrugineus weevils were associated with phoretic mites and the Index of Discrepancy values for Curculanoetus and Uroobovella indicated highly aggregated distributions of these mites on their weevil hosts. Uroobovella deutonymphs were significantly more prevalent than Curculanoetus. This is likely because of food availability and environment conduciveness.

The large numbers of Uroobovella and Curculanoetus, especially in the subelytral space, suggest that this microhabitat offers protection to the mites as the $R$. ferrugineus walk on the rough date palm tree trunk or under the dense fibers be-
between frond bases. From our field observations, this habitat was also the preferred daytime location of the weevils. The subelytral space probably also gives the mites protection against desiccation in the extremely arid and hot desert climate of UAE. It can also provide phoretic mites a form of protection against predatory mites, since larger predatory mites such as *Hypoaspis* sp. usually remain on the surface of beetles as they seek prey (Costa 1971). Given that the subelytral space appears to be the best choice for phoretic mites, other areas of the host insect, such as membrane wings are likely secondarily populated as subelytral spaces become overcrowded. One additional possible explanation of the subelytra preference is that in Coleoptera the elytra are not used actively in flight, but the membrane wings vibrate strongly during flight. Our findings on mite distributions on *R. ferrugineus* body regions were also consistent with findings of Atakan et al. (2009) and Bajerlein and Bloszyk (2004). It is likely that the low numbers of mites on other body regions could also be due to overcrowding in the preferred subelytral space.

*Curculanoetus* deutonymphs were found aggregating in the subelytral space near the base of the elytron and inside a small groove in that region. Because they were minuscule compared to the size of *U. orbicularis* and *Uroobovella* they could easily go unnoticed. A clear spatial separation was noticed between the deutonymphs of *Curculanoetus* and *Uroobovella* on the elytron. This could be explained by territoriality or by the presence of specific elytral morphological advantages utilized by each mite group. Members of the family Histiostomatidae have been reported to be involved in phoretic associations with other insects: *Histioptoma* sp., on palm weevils of the genus *Rhynchophorus* (Curculionidae: Coleoptera) (Houck 1994), *H. formosana* on three subterranean termite species (Isoptera: Rhinotermitidae) (Wang et al. 2002), *Histioptoma* sp. on *Cambala reddelli* millipedes (Cokendolpher & Polyak 1996), and *C. rhynchophorus* on *R. phoenicis* (Fain 1974).

A limited number of phoretic uropodid and histiostomatid mites can reasonably disperse on a *R. ferrugineus* host without an obvious impact on the

![Fig. 2. Deutonymph of *Uroobovella* sp. (A) SEM dorsal view; (B) under light microscope (×100).](image)

### Table 1. Comparison of loads of *Curculanoetus* sp. and *Uroobovella* sp. mites on *Rhynchophorus ferrugineus*.

<table>
<thead>
<tr>
<th>D</th>
<th>Mean Intensity</th>
<th>Mean Abundance</th>
<th>Prevalence</th>
<th>Range</th>
<th>Mean Intensity</th>
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<tr>
<td>0-93</td>
<td>17.1 (10.5-25.7)</td>
<td>3.6 (1.7-7.9)</td>
<td>21.2 (11.3-36.8)</td>
<td>0.929 <em>Curculanoetus</em></td>
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<tr>
<td>0-598</td>
<td>63.8 (53.8-72.9)</td>
<td>40.2 (26.5-62.1)</td>
<td>62.9 (42.9-94.6)</td>
<td>0.802 <em>Uroobovella</em></td>
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Values in parentheses indicate 95% confidence levels for mean abundance, mean intensity, and prevalence computed using 2000 replications. D = Index of Discrepancy; N = 105 adults of *R. ferrugineus*. 
weevil’s ability to fly. However, excessively large numbers on an individual insect could be a burden and may limit the insect’s flight performance. It is unknown if phoretic *U. orbicularis*, *Urobovella*, and *Curculanoetus* could have a detrimental impact to the host, if, by virtue of their presence in extremely large numbers. Such potential negative impacts may include reduction in the efficiency of foraging activities or of movement, making the weevils more susceptible to predation. Therefore, behavioral experiments need to be performed to illustrate if high mite loads are detrimental to *R. ferrugineus*. The negative impacts of phoresy could lead to parasitism and is often regarded as a transition between phoresy and parasitism (Houck & Cohen 1995). Parasitism generally implies some sort of transfer of resources and an associated negative effect on reproductive success of the host. Many mites live on hosts without seemingly harming them (Krantz 1978; Houck & O’Connor 1991). However, quantitative estimates with regard to this aspect of phoresy are limited. For example, Houck and Cohen (1995) documented a transfer of fluid from the hemolymph of the host beetle into the ‘phoretic’ mite, suggesting a first step toward parasitism. It has been demonstrated that *Rhyzopertha dominica* (Coleoptera: Bostrichidae) adult take-off ability was significantly decreased in the presence of high mite loads (>7 mites per host) of phoretic mites (Rocha et al. 2009). Elzinga and Broce (1988) mentioned that house flies (Diptera: Muscidae) were so burdened with histiostomatid hypopi that they were unable to fly or exhibit normal behavior.

In this study it was noticed that phoresy was not a mandatory choice for every *Uoorobovella* deutonymph. Many of these deutonymphs were observed in large numbers inside and outside cocoons moving freely on the fibers and on the pupal cast skin while adult weevils emerged from these cocoons carrying phoretic deutonymphs (Al-Deeb, unpublished data). Finding a large number of deutonymphs near and on the non-flying stage (pupa) could be explained by shelter- and/or moisture-seeking inside the cocoon. This could also be an attempt of deutonymphs to be as near to the newly emerging adult weevil as possible in order to secure an attachment point on its body.

In addition to *Uoorobovella* deutonymphs, collembolans were observed on the fibers of some of the cocoons of *R. ferrugineus*. Numbers of mites and collembolans increased considerably with increasing stages of decay at 25 °C in the laboratory. Eventually fibers dried out and resembled sawdust. Decaying plant matter can provide food directly or indirectly for many invertebrates (Lasebikan 1977). In our study, soil is the likely source of microarthropod (mites and collembolans) colonization of the cocoons. Our laboratory observations suggest that mites and collembolans progressively build up their populations as decomposition progresses. Additionally, we observed few uropodid adults on and in the dry remains of decaying dead bodies of *R. ferrugineus* adults.

This study did not investigate what mechanism attracted the phoretic mites to the *R. ferrugineus* weevils. However, it is known that *R. ferrugineus* males produce aggregation pheromones (Oehlschlager et al. 1995) to attract individuals of the same species. *Uropoda orbicularis*, *Urobovella*, and *Curculanoetus* mites probably use these pheromones to find potential hosts. Nigret et al. (2006) showed that the phoretic mite *Macrocheles saceri* (Acari: Mesostigmata) used semiochemicals of the cuticle as kairomonal signals to differentiate and locate *Scarabaeus* dung beetle hosts (Coleoptera: Scarabaeidae). Behavioral experiments are warranted to elucidate the mite attraction process to *R. ferrugineus*.

In conclusion, this study documented preferential distribution of phoretic *U. orbicularis* and *Uoorobovella* sp. on *R. ferrugineus* weevils in palm trees. It also documented the presence of phoretic *Curculanoetus* sp. deutonymphs on this insect pest and the presence of collembolans on the cocoon fibers. The interactions between these species are not necessarily straightforward and need further careful studies. Collectively, *Curculanoetus* and *Uoorobovella* were numerically abundant on *R. ferrugineus* and the effects of this association may be more detrimental to the host than suggested by mere phoresy. The possible detrimental role of excessive phoretic mites on the weevils needs further investigation. Large field surveys on microarthropods in date palm plantations is warranted as there is the possibility of finding local natural enemies, especially on eggs or neonates, which could be used in successful biological control of *R. ferrugineus*. To our knowledge, this study is the first record of *U. orbicularis*, *Uoorobovella* sp., and *Curculanoetus* sp. mites in UAE.

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**Fig. 3.** The distribution of *Curculanoetus* sp. *Uoorobovella* sp. deutonymphs on different regions of male and female *R. ferrugineus*.
ACKNOWLEDGMENTS

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Fig. 4. (A) Curculanoetus sp. deutonymphs on subelytron; (B, C) Uroobovella sp. deutonymphs on subelytron under dissecting stereoscope; (D) Curculanoetus sp. dorsal view (×400); (E) Curculanoetus sp. ventral view showing sucker plate (×1000) under light microscope.


