J. Acarol. Soc. Jpn., 25(S1): 161-167. March 25, 2016

Trophic habits of mesostigmatid mites associated with bark beetles in Mexico

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ABSTRACT

Samples of bark and logs damaged by bark beetles were collected from 16 states of Mexico from 2007 to 2012. Fifteen bark beetle species were found within the bark and log samples and were examined for phoretic mites and arthropod associates. Thirty-three species of mesostigmatid mites were discovered within the samples. They were identified in several trophic guilds based on the mites' feeding habits if known. Over half of the 33 mite species were found to be predators feeding on arthropods or nematodes, with the most voracious mites in this study being *Dendrolaelaps quadrisetus*, *Hypoaspis* (*Cosmolaelaps*) *vacua, Macrocheles boudreauxi*, *Proctolaelaps dendroctoni*, and *Schiztothetus lyriformis*.

Key words: predation, nematophagous, bark, phoretic, Mexico, bark beetles

INTRODUCTION

The mesostigmatid mites or gamasid mites (Parasitiformes: Mesostigmata) are the most abundant and diverse taxa among arthropods and are generally regarded as predators (Walter et al. 1987). They play an important role in food webs (Moore et al. 1988), and some are known to have potential as biological control agents (Lesna et al. 1995; Wiethoff et al. 2004). However, the feeding behavior of many species belonging to Mesostigmata is largely unknown, mainly for those species inhabiting microecosystems such as tree bark. Tree bark microecosystems have many mesostigmatid mite families present, as well as a wide range of organisms that might be potential prey for these predators.

The diet of mesostigmatid mites mainly consists of lightly sclerotized arthropods such as mites, springtails, and insect eggs or juveniles, with rare instances of feeding on fungal hyphae

Tetsuo GOTOH and DeMar TAYLOR (eds.), Acarology XIV: Proceedings of the International Congress. *Journal of Acarological Society of Japan* 25 (Suppl. 1): 1-192.
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DOI: 10.2300/acari.25.Suppl_161

and spores (Walter and Ikonen 1989; Walter and Lindquist 1989; Walter et al. 1987), as well as nematodes and small earthworms (Beaulieu and Walter 2006). Mesostigmatids are sometimes considered specialist mites, as they include in their diet only a single prey type of either nematodes or arthropods, yet they feed on a wide variety of organisms within each type. A few mesostigmatids have been reported to consume mainly fungal spores, bacteria, and other microorganisms associated with decaying plant matter, although it is likely that most of these species also include nematodes and soft-bodied arthropods in their diet (Athias-Binche 1981; Nawar et al. 1993).

The dietary habits of mites associated with bark beetles are not yet completely understood. Among mites inhabiting soil and other cryptic habitats, most studies suggested they are predators of arthropods and nematodes (Chaires-Grijalva et al., 2013).

MATERIALS AND METHODS

Between 2007 and 2012, samples of barks and logs showing signs of damage by bark beetles belonging to the subfamily Scolytinae were obtained from 16 states of Mexico (Aguascalientes, Baja California, Chihuahua, Coahuila, México State, Hidalgo, Jalisco, Morelos, Michoacán, Nuevo León, Oaxaca, Puebla, Querétaro, Tlaxcala, Veracruz, and Zacatecas). The samples were collected in plastic bags and transported to the Acarology Laboratory for later review. We collected and reviewed 2203 bark beetles of 15 species of *Dendroctonu*s, *Ips*, and *Pseudoips* (*Dendroctonus adjunctus, D. brevicomis, D. frontalis, D. mexicanus, D. pseudotsugae, D. rhizophagus, D. valens, Ips bonanseai, I. calligraphus, I. confusus, I. cribicollis, I. grandicollis, I. integer, I. lecontei*, and *Pseudoips mexicanus*). Upon inspecting the samples for mites and other phoretic associates, 774 mesostigmatid mites associated with these insects were collected and reviewed.

Bark beetles and associated arthropods were collected from the bark and log samples using forceps and placed into separate vials of ethanol. Mites and other associates attached to the collected bark beetles were removed from each individual bark beetle and placed in a solution of lactic acid to clear. The mites were removed from the lactic acid solution and mounted onto glass slides using Hoyer's medium and assessed under a stereoscope for identification. In addition to the phoretic associates collected on bark beetles, mites and other organisms found in the bark beetle galleries were also collected and observed.

Additionally, one mite species (*Hypoaspis* (*Cosmolaelaps*)*vacua*) was cultured at 25℃ in plastic bottles containing a substrate of gypsum, charcoal, and organic matter. The mites were observed five times for 10 h under a microscope. The mite cultures were mainly fed with astigmatid mites (*Rhizoglyphus* spp. and *Sancassania* spp.; Fig. 1) and nematodes. Each day, 5 deutonymphs and 10 adult astigmatid mites and nematodes were introduced to the cultures to feed the mesostigmatid mites present in them. The feeding habits were observed and recorded.

RESULTS AND DISCUSSION

A total of 2203 bark beetles represented by 15 beetle species were collected in Mexico and

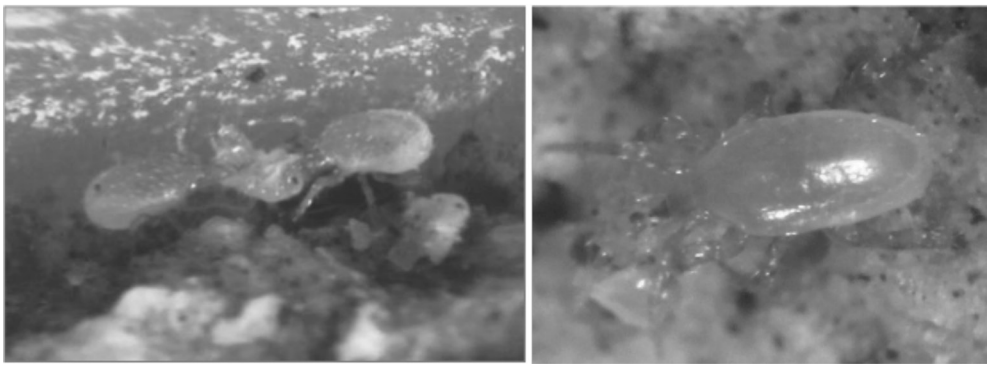

Fig. 1 Predatory mites feeding on astigmatids.

examined in this study. More than 774 mites were found to be associated with these bark beetles. These mites belong to 33 species of mesostigmatid mites and were divided into trophic guilds based on their feeding habits if known. Table 1 details the trophic habit of the mite species found and their main food observed, unless unknown, with 18 of the 33 species identified as predaceous or nematophagous.

Among the most voracious predators found in this study were *Dendrolaelaps quadrisetus*, *Hypoaspis* (*Cosmolaelaps*) nr. *vacua*, *Macrocheles boudreauxi*, *Proctolaelaps dendroctoni*, and *Schiztothetus lyriformis*, which feed on other mites (larvae and protonymphs of digamaselids and trematurids) inhabiting the galleries. Active predation is the dominant lifestyle among the Mesostigmata that have been studied (Karg 1993; Krantz 2009; Walter and Proctor 1999).

It is noteworthy that we observed *D. quadrisetus*, *H. vacua*, and *Lasioseius safroi* feeding on immature stages of astigmatid mites in the galleries, but they were not observed to attack the eggs or larvae inside the bark, as noted previously (Kinn 1983a, 1983b; Lindquist 1969; Moser 1975). Past research indicated that all mesostigmatid mites attack the eggs and larvae of bark beetles present in the galleries, but only *D. quadrisetus* mainly feeds on nematodes present in galleries (Moser 1995). André (1980) noted that a strong preference of a phoretic mite for a particular host does not necessarily mean that the mite will utilize that host as a food source.

Some mite species, such as *H. vacua*, show cannibalism and feed on conspecifics, especially eggs, larvae, and protonymphs. Females were the most voracious predators, feeding of at least a dozen larvae and protonymphs preys. Sometimes *H. vacua* individuals were found feeding on dead bodies, although some of the dead bodies had already been colonized by fungi. Seastedt et al. (1981) suggested that some mesostigmatids feed on the liquid in decomposed arthropods. However, the diet of a generalist predator is known to be limited by the vulnerability of prey, depending on factors such as body size, speed, and thickness of the cuticle, as well as the spatial or temporal distribution and behavioral and physiological mechanisms of defense by prey (Walter and Ikonen 1989). Smaller and less sclerotized organisms are generally the most attacked.

In this regard, Walter (1988) noted that most Mesostigmata are generalist predators because they feed on several kinds of organisms. Moser (1975) reported that alternative foods for predators in galleries are usually eggs and early larval instars of bark beetles, other mites, and

Table 1. Trophic guilds of mesostigmatid mites associated with bark beetles in Mexico.

Mite family	Mite species	Trophic habit	Food source
Sejidae	*Sejus boliviensis* Hirschmann & Kaczmarek, 1991	generalist predator	nematodes and small arthropods
Nenteriidae	*Nenteria breviunguiculata* Willmann, 1949	generalist predator	small arthropods
Trematuridae	*Trichouropoda adjuncti* Wisniewski & Hirschmann, 1988	omnivore	nematodes, fungi, eggs and larvae of bark beetles
	Trichouropoda australis Hirschmann, 1972	omnivore	nematodes, fungi, eggs and larvae of bark beetles
	Trichouropoda fallax Vitzthum, 1926	unknown	
	Trichouropoda hondurasae Hirschmann & Wisniewski, 1986	unknown	
	Trichouropoda ovalis Koch, 1939	fungivore	diverse species
	Trichouropoda polytricha Vitzthum, 1923	omnivore	nematodes, fungi, eggs and larvae of bark beetles
	Trichouropoda n. sp. 1	unknown	
	Trichouropoda n. sp. 2	unknown	
	Trichouropoda n. sp. 3	unknown	
	Trichouropoda n.sp. 4	unknown	
	Trichouropoda n.sp. 5	unknown	
Parasitidae	*Schizosthetus lyriformis* (McGraw and Farrier, 1969)	Predator, nematophagous	nematodes and small mites
Digamasellidae	*Dendrolaelaps neocornutus* (Hurlbutt, 1967)	predator	eggs and larvae of bark beetles
	Dendrolaelaps neodisetus Hurlbutt, 1967	predator nematophagous	eggs and larvae of bark beetles, nematodes
	Dendrolaelaps n.sp.	unknown	
	Dendrolaelaps quadrisetus Berlese, 1920	predator nematophagous	nematodes, eggs and larvae of bark beetles
Macrochelidae	*Macrocheles boudreauxi* Krantz, 1965	predator nematophagous	nematodes, eggs and larvae of bark beetles
	Macrocheles sp 1.	unknown	
Ascidae	*Arctoseius cetratus* Sellnick, 1940	omnivore	Fungi, nematodes, springtails, eggs and larvae of bark beetles, other mites
	Arctoseius semicissus Berlese, 1892	unknown	
	Asca pini Hurlbutt, 1963	predator	eggs and larvae of bark beetles, other mites
	Lasioseius cortiseius Lindquist, 1971	predator	eggs and larvae of bark beetles, other mites
	Lasioseius dentatus Fox, 1946	unknown	
	Lasioseius imitans Berlese, 1910	unknown	
	Lasioseius safroi Ewing, 1920	predator	eggs and larvae of bark beetles, other mites
Melicharidae	*Proctolaelaps dendroctoni* Lindquist & Hunter 1965	predator	eggs and larvae of bark beetles, other mites
	Proctolaelaps hystricoides Lindquist & Hunter 1965	omnivore	nematodes, fungi, eggs and larvae of bark beetles
	Proctolaelaps hyxtris Vitzthum, 1923	predator	eggs and larvae of bark beetles, other mites
	Proctolaelaps subcorticalis Lindquist, 1971	predator	eggs and larvae of bark beetles, other mites
Laelapidae	*Androlaelaps casalis* Berlese, 1887	predator	eggs and larvae of bark beetles, other mites
	Hypoaspis vacua Michael, 1891	predator	other mites

nematodes. Eggs are usually unattractive to many predators because of the thick chorion in their stationary state. However, larger species of Mesostigmata such as those in the families Macrochelidae, Parasitidae, and Laelapidae feed on insect eggs (Halliday 1990, 1993).

In addition to mites, hundreds or thousands of nematodes are regularly found under the elytra of several species of *Dendroctonus*. These phoretic nematodes use the beetle as a mode of transport in order to seek new, appropriate sites. Some mites feed on the nematodes during the phoretic association (Tamura and Enda 1980), but not all stages tend to feed on nematodes. Mites such as *S. lyriformis* feed on nematodes only in the larval stages, whereas *D. quadrisetus* deutonymphs and adults feed on nematodes. Nymphs and adult mites that feed on nematodes may be effective biological control agents (Klepzig et al. 2001). *Dendrolaelaps neodisetus* prefers nematodes over other prey, although Moser (1975) and Kinn (1983b) reported that many nematophagous mites attack and kill other types of mites.

Nematodes observed within the galleries are a natural prey for mites. Nematophagous mites such as *D. neodisetus* may be beneficial for the development of bark beetles because, within this mutual association, the mite feeds on the nematode *Contortylenchus brevicomi* (Kinn 1983b). Nematodes seem to be a food resource for the mites, leading to faster development and better reproductive performance in several Mesostigmata (Walter et al. 1987).

Other arthropods were found in these bark beetle samples, including springtails, psocoptera, and oribatid and astigmatid mites at all stages of development.

The relationship between the food webs in the galleries and on the bark beetles can be complicated. Therefore, one cannot discuss the mites without considering the host insect, fungi, nematodes, and other organisms cohabiting this microecosystem. According to Moser (1995), the closer the phoretic relationship between a mite and bark beetle as measured by the association/predation index of Wilson (1980), the less of a threat the mites are to the beetle. Therefore, the mite species with a low rate of association may have a high probability of predation.

Furthermore, because of their phoretic habits, subcortical mites may be host specific. However, most of the mites in the food web are probably more specific to the habitat than to the beetle. For example, Lindquist (1969) reported that *Proctolaelaps hystricoides* tends to have a more specific habitat because it is associated with several species of *Dendroctonus*, *Ips*, and *Orthotomicus*.

The introduction and manipulation of new or exotic species as natural enemies against scolytines seem to have little chance of success. This is because almost all associated species are well adapted to Scolytinae, being endemic in some cases and with a complex of many biotic associates. However, Miller et al. (1987) suggested that biological control of bark beetles has never been attempted in earnest in the United States and should be reconsidered in light of the theory of "new partnerships," in which some mites are attracted to the pheromones of some bark beetles. The partnership between phoretic mites and bark beetles should be exploited to assess the potential for biological control (Pimentel 1963).

The present results confirmed that predation is the main trophic habit in mesostigmatid mites associated with bark beetles in Mexico. Nematodes are widely accepted food for mesostigmatid mites, and they can be consumed by a variety of mites. We confirmed that there are more than 30 mesostigmatid mite species phoretic on bark beetles in Mexico, and that these mites—particularly *D. quadrisetus*, *H. vacua*, *M. boudreauxi*, *P. dendroctoni*, and *S. lyriformis*—play an important role as predators in the tree bark habitat.

It is important to survey the mites associated with bark beetles biology, ecology, behavior, food, and the aspects of host specificity and interactions between species. This will provide tools

to use the mites as biological indicators and as candidate biological control agents for reducing populations of bark beetles.

ACKNOWLEDGEMENTS

We thanks Dr. Víctor Arriola (Instituto Nacional de Investigación Forestal y Agropecuaria), Dr. Gerardo Zúñiga (Escuela Nacional de Ciencias Biológicas) for the logs, barks and bark beetles. Dr. Jesús Acuña for collecting parts of biological material. To Abril Morales by the technical review of the manuscript.

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