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Cover image: Cactus lady beetle, *Chilocorus cacti*, preying on citrus snow scale, *Unaspis citri*, on Persian lemon. Photo credit: Edgardo Cortez-Mondace, INIFAP-Campo Experimental Valle del Fuerte, Sinaloa, México.

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Natural Enemies Associated with Citrus Flat Mite¹ in a Commercial Orchard of Persian Lime at Sinaloa, México

Edgardo Cortez-Mondaca², Guillermo Gutiérrez-Soto³, Teresa Santillan-Galicia⁴, Fernando Alberto Valenzuela-Escoboza³, Miguel Ángel López^{2*}, and Álvaro Ortiz Osuna⁵

Abstract. From 18 samplings at 2-week intervals with yellow impaction traps, entomological net, and direct observation, natural enemies of the citrus flat mite, *Brevipalpus californicus* (Banks), were determined in a commercial orchard of Persian lime, *Citrus x latifolia* Tanaka Ex. Q. Jiménez: lady beetles, *Stethorus pinachi* (Gordon y Chapin), *Cycloneda sanguinea* (L.), and *Chilocorus cacti* (L.); lacewing, *Chrysoperla* spp.; pirate bug, *Orius* sp.; assassin bug, *Zelus* spp.; big eyed bug, *Geocoris* sp., and mites *Phytoseiulus persimilis* (Athias-Henriot), *Amblyseius largoensis* (Muma), *Euseius scutalis* (Athias-Henriot), *Neoseiulus cucumeris* (Oudemans), *Propioseiusopsis* sp., and *Chelotimus* sp. The study is the first formal report of entomophages associated with *B. californicus* in Persian lime at Sinaloa, Mexico.

Introduction

Feeding by the citrus flat mite, *Brevipalpus californicus* (Banks) (Acari: Tenuipalpidae), severely retards growth of new shoots of *Citrus*. Leaves do not develop from the affected gill-shaped terminal buds (Childers et al. 2003). *B. californicus* also helps transmit greasy spot fungus, *Zasmidium citri-griseum* (F.E. Fisher) U. Braun & P.W. Crous, that severely affects the Persian lime, *Citrus x latifolia* Tanaka Ex. Q. Jiménez, crop in southern Sinaloa (García-León and Cortez-Mondaca 2020). Species of the genus *Brevipalpus*, including *B. californicus*, are vectors of citrus leprosis caused by *Citrus leprosis virus* (CiLV) that directly reduces production and shelf life of citrus (Rodríguez et al. 2003). Management of the pest in citrus fruit at Sinaloa is by chemical control with synthetic acaricides. Other options are needed for management. The objective of the study was to determine natural enemies of citrus flat mite in a commercial orchard of Persian lime.

¹*Brevipalpus californicus* (Banks) (Acari: Tenuipalpidae).

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Materials and Methods

The study was in a 3-year-old commercial orchard of Persian lime (N 24°40'58.026" and W 107°43'53.0256") near El Potrero de Sataya, Navolato, Sinaloa. Eighteen samplings were done every 14 days from September 2020 to June 2021. Techniques used were: 1) yellow impaction traps: yellow traps with entomological glue in the canopy of 10 Persian lime trees, chosen randomly and changed every 14 days; 2) entomological net: 100 blows of the net were done at five sites (each corner and in the center) in the orchard; 3) direct inspection of leaves and fruit with a 20X hand magnifying glass where *B. californicus* was present. Predators at close range (20 cm) or preying on citrus flat mites were collected by using a mouth aspirator or brush. They were put into 70% ethyl alcohol in Eppendorf tubes (1.5 ml) or plastic cups with lids (100 ml). The specimens collected from the different types of sampling were labeled and transferred to the entomology laboratory of Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias-Campo Experimental Valle del Fuerte, at Juan José Ríos, Sinaloa, where they were identified with the aid of a Carl Zeiss® Stemi 2000 microscope, using taxonomic keys by Werner (1978), Gordon (1985, 2000), and Brooks (1994). Predator mites were identified at the Laboratorio de Acarología del Posgrado de Fitosanidad, Colegio de Postgraduados, Campus Montecillo, using taxonomic keys by Baker and Tuttle (1987), Gerson et al. (1999), Walter (2006), Minor (2008), Tixier et al. (2013), Beard et al. (2015), and Kamran et al. (2018). Predators collected are listed in Table 1.

Results

An interesting diversity of species and abundance of predators associated with citrus flat mite were obtained, which can be used for biological control by conservation or by augmentation. Some species found already were reported in previous studies, such as lady beetles of the genus *Stethorus* that feed on citrus flat mite (Palomares-

Table 1. Predators and Number of Specimens Collected Associated with *Brevipalpus californicus* in a Persian Lime Orchard at Potrero de Sataya, Navolato, Sinaloa

Predator (species)	Order and Family	Total
<i>Stethorus pinachi</i> (Gordon y Chapin)	Coleoptera: Coccinellidae	108
<i>Chrysoperla</i> spp.	Neuroptera: Chrysopidae	30
<i>Cycloneda sanguinea</i> (L.)	Coleoptera: Coccinellidae	17
<i>Olla v-nigrum</i> (Mulsant)	Coleoptera: Coccinellidae	10
<i>Hippodamia convergens</i> (G-M)	Coleoptera: Coccinellidae	9
<i>Orius</i> sp.	Hemiptera: Anthocoridae	8
<i>Coleomegilla maculata</i> (De Geer)	Coleoptera: Coccinellidae	7
<i>Phytoseiulus persimilis</i> (Athias-Henriot)	Acari: Phytoseiidae	6
<i>Zelus</i> spp.	Hemiptera: Reduviidae	7
<i>Neoseiulus cucumeris</i> (Oudemans)	Acari: Phytoseiidae	4
<i>Geocoris</i> sp.	Hemiptera: Geocoridae	3
<i>Chilocorus cacti</i> (L.)	Coleoptera: Coccinellidae	3
<i>Amblyseius largoensis</i> (Muma)	Acari: Phytoseiidae	3
<i>Propioseiusopsis</i> sp.	Acari: Phytoseiidae	2
<i>Euseius scutalis</i> (Athias-Henriot)	Acari: Phytoseiidae	2
<i>Cheletomimus</i> sp.	Acari: Cheyletidae	2

Pérez et al. 2021), red citrus mite, *Panonychus citri* McGregor (Acari: Tetranychidae) (Guanilo and Martínez 2007), and assassin bug, *Zelus renardii* Kolenati. The twice-stabbed lady beetle, *C. cacti*, a predatory beetle of phytophagous mites, is a natural enemy of the red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae) (Machkour-M'rabet et al. 2015). Neuroptera of the genus *Chrysoperla* feed on immature and adult avocado red mite, *Oligonychus yothersi* McGregor (Acari: Tetranychidae), keeping abundance below the economic threshold (Badii et al. 2010). Lacewing larvae feed on adults of red citrus mite (*P. citri*) (Guanilo and Martínez 2007). Hemiptera of the genera *Geocoris* and *Orius* are natural enemies of red spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae). In some laboratories, red spider mite is used as food for breeding beneficial predators (González-Cabrera 2003). Species of the genera *Amblyseius*, *Euseius*, *Neoseiulus*, *Phytoseiulus*, and *Propioseius* are predators of mites of the genus *Brevipalpus* (Childers et al. 2003, González 2005, Núñez 2005, Ruiz et al. 2006, Guanilo and Martínez 2007, CABI 2019, 2020). Predatory mites of the genus *Cheletomimus* also have been reported preying on phytophagous mites in coconuts, *Cocos nucifera* (L.) (Arecaceae) (Hastie et al. 2010).

CABI (2020) reported *E. scutalis* as a predator of *B. californicus*, and *P. persimilis* is reproduced and sold commercially as a biological control agent of citrus flat mite and other pest mites. Palomares-Pérez et al. (2021) found *A. largoensis* associated with *Brevipalpus* spp. in orange trees, *Citrus x sinensis* Osbeck, at two locations of the State of Colima, Mexico. Argolo et al. (2020) indicated releases of *A. largoensis* effectively suppressed *B. yothersi* (Baker) and damage to citrus to be an effective biological control agent and important in IPM programs to control citrus leprosis. *N. cucumeris* is commercially available as a biological control agent for a wide range of prey including some mites, but is not specified for *Brevipalpus* spp. (Kakkar and Kumar 2016).

In the guild of predatory species in the study, coleopterans, neuropterans, and hemipterans were abundant generalist predators of prey of different taxa in citrus. Predatory mites, especially Phytoseiidae, although they prey on other species of mites and some species of thrips, are more specific and because of their close taxonomic relationship, have bioecology similar to that of their prey, so are better candidates for biological control by augmentation. Some species also can survive on alternate food like pollen (Nunes et al. 2020). This study is the first formal report of entomophages associated with *B. californicus* in Persian lime at Sinaloa, Mexico.

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