Systematic & Applied Acarology 24(12): 2537–2551 (2019)
http://doi.org/10.11158/saa.24.12.17

ISSN 1362-1971 (print)
ISSN 2056-6069 (online)

Article

Mites associated to chile piquín (*Capsicum annuum* L. var. *glabriusculum*) in two Protect Natural Areas in Northeastern México

JOSÉ IRVING MONJARÁS-BARRERA[1,2], JULIO CESAR CHACÓN-HERNANDEZ[2*], GUILHERME LIBERATO DA SILVA[3], LIANA JOHANN[3], ONILDA SANTOS DA SILVA[4], JERONIMO LANDEROS-FLORES[5], VENANCIO VANOYE-ELIGIO[2], FRANCISCO REYES-ZEPEDA[2] & NOELI JUAREZ FERLA[3]

[1]Doctorado en Ecología y Manejo de Recursos Naturales en el Instituto de Ecología Aplicada de la Universidad Autónoma de Tamaulipas, Instituto de Ecología Aplicada, División del Golfo 356, Colonia Libertad, C.P. 87019. Ciudad Victoria, Tamaulipas, México.

[2]Universidad Autónoma de Tamaulipas, Instituto de Ecología Aplicada, División del Golfo 356, Colonia Libertad, C.P. 87019. Ciudad Victoria, Tamaulipas, México.

[3]Laboratório de Acarologia, Universidade do Vale do Taquari - Univates, Lajeado, 95914-014, Rio Grande do Sul, Brasil.

[4]Departamento de Microbiologia, Imunologia e Parasitologia, Universidade Federal do Rio Grande do Sul. 90050-170 Porto Alegre, Rio Grande do Sul, Brasil.

[5]Universidad Autónoma Agraria Antonio Narro, Departamento de Parasitología. Calzada Antonio Narro, 1923, CP 25315, Buenavista, Saltillo, Coahuila, México.

**Corresponding author: jchacon@docentes.uat.edu.mx*

Abstract

The conservation status of an ecosystem is checked by studying the composition and diversity of the organisms that interact in trophic chains. The aim of this study was to evaluate the biodiversity of mites associated to *Capsicum annuum* L. var *glabriusculum* (Solanaceae) at three sampling sites corresponding to two Protected Natural Areas (PNA) in Tamaulipas state, Mexico. Samplings were carried out in "Cañón de la Peregrina" and "Altas Cumbres" situated in the PNA "Altas Cumbres" and "Ojo de Agua", located in the "El Cielo" Biosphere Reserve. Mite diversity was $H = 1.09 \pm 0.14$ in Ojo de Agua, and it was $H = 1.08 \pm 0.08$ and $H = 1.11 \pm 0.06$ in Altas Cumbres and Cañón de la Peregrina, respectively. A total of 47 species were identified belonging to 35 genera of 18 families associated to *C. annuum* L. var *glabriusculum* in Mexico. Predatory mite richness was higher than that of generalist and phytophagous mites (31, 11 and 5 species, respectively) for the two ANP. The similarity index of Jaccard between OA–AC ($I_J = 0.257$; $P < 0.05$), CP–AC ($I_J = 0.293$; $P < 0.05$) and AC–CP ($I_J = 0.324$; $P < 0.05$) was low. *Pseudopronematalus* sp. 4 (Iolinidae) was predatory mite most abundant in both ANP ($P_i = 9.311$); followed by *Metaseiulus (Metaseiulus) negundinis* (Denmark) (Phytoseiidae) only for ANP "Altas Cumbres" ($P_i = 1.004$). While for phytophagus mite, *Aculops lycopersici* (Tryon) (Eriophyidae) and *Tetranychus merganser* Boudreaux (Tetranychidae) presented the highest abundances in all sites ($P_i = 79.919$ and 5.142, respectively). The high number of mites species associated to chile piquín suggests stability in the PNA despite anthropogenic activities, and that the PNA works as a mite reservoir.

Key words: Acari; biodiversity, Protected Natural Area, Altas Cumbres, El Cielo Biosphere Reserve

Introduction

The biogeographic composition of Mexico allows a mixture and co-occurrence of typical biota of Neotropical and Nearctic regions, which overlap to give origin to the components of the Mexican Transition Zone (MTZ) (Morrone 2005; Ferro & Morrone 2014). This provides physical and environmental characteristics, as well as ecological factors that provides Mexico with one of the highest biodiversity in the world and endemism levels that is extensive in several taxa (Dirzo 1992; Llorente-Bousquets & Morrone 2002). For this reason, Protected Natural Areas (PNA) implement strategies for the conservation of biodiversity and the adequate use of natural resources (Villalobos 2000; Iñiguez *et al*. 2014).

Mexico includes 176 PNA with different conservation statuses, distributed in 41 Biosphere Reserves, 5 Monuments, 67 National Parks, 8 Protected Areas of Natural Resources, 37 Protected Areas of Flora and Fauna, and 18 Sanctuaries (González-Ocampo *et al.* 2015). The PNA "Altas Cumbres" and the "El Cielo" Biosphere Reserve are located in Tamaulipas state, within the MTZ, with diversity of fauna and flora (Morrone 2005; Herrera-Izaguirre *et al*. 2014). Hernández *et al*. (1991) recorded 610 species of plants useful to humans, 30% of which are edible, e.g. chile piquín (*Capsicum annuum* L. var. *glabriusculum*) (Solanacea). Chile piquín is important both from the social and economic viewpoints, since 65% of inhabitants of rural localities, including PNA, depend on its sale and self-consumption (Kraft *et al*. 2013; Aguirre-Hernández *et al*. 2017).

In México, it is estimated that occur 2,680 species of mites (Hoffman & López-Campos 2002; Pérez *et al*. 2014; Acuña-Soto *et al*. 2015; Vázquez & Klompen 2015; Vázquez-Rojas *et al*. 2015; Ojeda *et al*. 2016; Paredes-León *et al.* 2016; Acuña-Soto *et al*. 2017; Mejía-Recamier & Palacios-Vargas 2018; Páez *et al*. 2019; Trejo-Palacios *et al*. 2019). However, there are few studies on mite diversity and arthropods in PNA of Tamaulipas and Mexico (Ruíz-Cancino & Coronado 2002). Although little is known about phytophagous mites on commercial varieties of *C. annuum* in Mexico (Estebanes-Gonzales & Rodriguez-Navarro 1991; Migeon & Dorkeld 2019). *C. annuum* L. var. *glabriusculum* is not a commercial crop despite its wide distribution in the American Continent (Mireles-Rodríguez *et al*. 2015; Hayano-Kanashiro *et al*. 2016), and their associated mites are unknown. Therefore, knowledge of mite diversity and its importance for the conservation of natural enemies is limited (Bucio-Soto *et al*. 2016; Landis *et al*. 2000; Çobanoğlu & Kumral 2016). The aim of this study was to assess the biodiversity of mites associated to *Capsicum annuum* L. var. *glabriusculum* in two Protected Naturals Areas in Tamaulipas, Mexico.

Materials and methods

Study areas

Sampling sites were situated in “Cañón de la Peregrina” (CP) (23°46’41”N, 99°12’12”W) and “Altas Cumbres” (AC) (23°41’52”N, 99°11’04”W), located in the PNA "Altas Cumbres" in Victoria municipality, and “Ojo de Agua” (OA) (23 ° 01'7" N, 99 ° 08'54 "W), which is located in the "El Cielo" Biosphere Reserve in Gómez Farias municipality (Fig. 1). AC and CP are comprised of mountains with numerous reliefs; hillside (415 m.a.s.l.) and canyons (365 m.a.s.l.), respectively. With submontane scrub vegetation, the arboreal stratum has an average height of 5 m. Vegetation in OA is low sub-deciduous jungle (175 m.a.s.l.), with a mixture of deciduous and perennial species with an average height of 25 m.

For design of sampling for each site, was used a one-hectare quadrant considered the orography and natural distribution of wild plants of *C. annuum* L. var. *glabriusculum*. Therefore, for CP and OA a “W”-shaped transect was used. In AC it was a linear transect of 100 m long was used, due to “W”-shaped transect is interrupted by San Marcos stream and makes it impossible to carry out this type of transect. In both cases, transect width was 10 m sampling all plants of *C. annuum* L. var. *glabriusculum* that were inside it (Bautista *et al.* 2011). According to the data obtained from meteorological stations of Comisión Nacional del Agua (CONAGUA) from Victoria and Gómez Farias during the sampling period, maximum, minimum, and ambient temperature, as well as evaporation were, respectibely for Victoria 33.54 ± 3.24°C, 18.83 ± 3.87 °C, 20.22 ± 3.65 °C and 5.32 ± 1.49, and Gómez Farias 31.04 ± 2.65 °C, 20.54 ± 2.58 °C, 21.27 ± 2.39 °C and 3.75 ± 4.00.

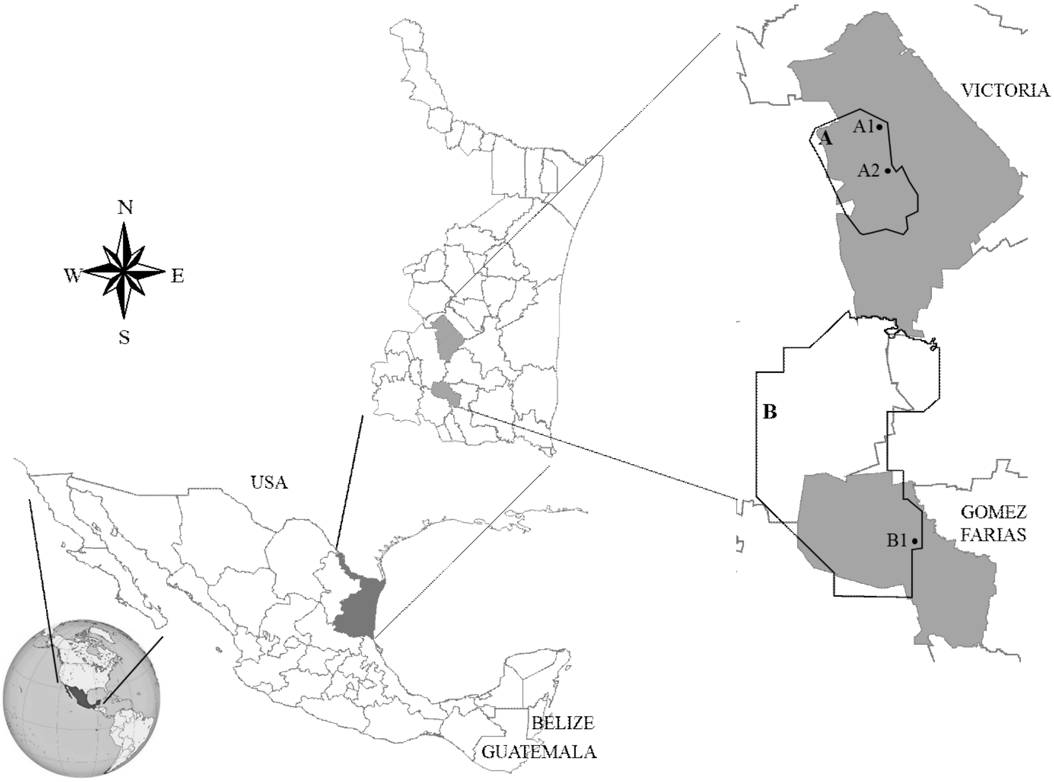

FIGURE 1. Sampling sites in Protected Natural Areas (PNA) in Tamaulipas. (A) PNA "Altas Cumbres": (A1) Altas Cumbres and (A2) Cañón de la Peregrina; (B) "El Cielo" Biosphere Reserve: (B1) Ojo de Agua.

Sampling and mite extraction

The wild plants of chile piquín in natural conditions not present high densities of leaves (Ramírez-Novoa *et al*. 2018). On the other hand, at the time of the collect of the fruit of chile piquín by local inhabitants, they cut vegetative parts or the complete plant decreasing the amount of leaves (Villalón-Mendoza *et al*. 2016). Therefore, the number of wild plants of *C. annuum* var. *glabriusculum* was 22 ± 1 (average ± SD) per site. Twenty-one random samples were carried out during ten months (February to November 2017) with intervals of 14 days between sampling, collecting 50 leaves per site per sampling. The samples were transported in "Ziploc" bags inside a dry ice cooler and submerged in a cooling gel at a temperature of 2 ± 1 ° C to the Laboratory of Population Ecology of the Institute of Applied Ecology of Autonomous University of Tamaulipas. All mites were counted directly from the leaves using a digital counter and a stereomicroscope. All mites, except for the 10% of females of Tetranychidae, were mounted directly on Hoyer´s medium (Dhooria, 2016). The identification of specimens was performed to the species level using a phase contrast light microscope and the following identifications keys: André (1980), Baker & Tuttle (1987), Baker & Tuttle (1994), Chant & McMurtry (2007), Fan & Li (1992), Fan *et* al. (2016), Gerson *et al*. (1999), Hernandes *et* al. (2016), Krantz & Walter (2009), Meyer & Ueckermann (1987), Moraes *et al*. (2016), Rehman *et al.* (2018), Silva *et al*. (2016), Skvarla *et al*. (2014) and Ueckermann & Grout (2007). The identification was carried out at Laboratório de Acarologia of the Universidade do Vale do Taquari - Univates, Lajeado, Rio Grande do Sul, Brazil.

Biodiversity parameters

Abundance was determined using the sum of mites per leaf (50 leaves) per sample (21 samplings) and the following equation was used to calculate the proportion of mites on chile piquín peppers (Çobanoğlu & Kumral 2016):

$$P_i = \frac{S_i}{\sum_{i=1}^{n} S_i} \text{ x } 100$$

Where P_i is the proportion of the i^{th} species, n is the total species number, and S_i is the numbers of individuals of the i^{th} species.

To explain the proportion of mite species per feeding habits mites, the P_i values of all the species by feeding habit were summed. The feeding habits for phytophagous, generalist (fungivores, scavenger or feeders on plant exudates and pollen) and predatory (selective, generalist and specialist; see McMurtry *et al.* 2013) mite were established according to literature: Aguilar & Murillo 2012, Badii *et al*. 2001, Baker *et al.* 1987, Castro & Den Heyer 2009, Ehara & Ueckermann 2006, Estebanes-Gonzales & Rodriguez-Navarro 1991, Gerson *et al.* 1999, Hernandes *et al.* 2016, Kamran & Alatawi 2014, Leiva *et al.* 2013, Meyer & Ueckermann 1987, Moraes *et al.* 2004, Moraes *et al.* 2016, Silva *et al.* 2014 and Silva *et al.* 2017.

Mite biodiversity level on chile piquín per site and feeding habit was estimated using the Shannon index (*H'*) (Magurran 2004):

$$H' = -\sum_{i=1}^{S} (p_i \ln p_i)$$

Where S is the total number of species in the community (richness), p_i is the proportion of S represented by the i^{th} species, and ln p_i is the natural logarithm of this proportion (Magurran 2004; Çobanoğlu & Kumral 2016).

The Jaccard index (I_J) was used to measure the degree of similarity between sites:

$$I_J = \frac{c}{a+b-c}$$

Where a is the number of species present at site A, b is the number of species at site B, and c is the number of species in both sites, A and B.

Data analysis

The *Jackknife* method was used to compare the Shannon index among sites and mite feeding habits (Friedl & Stampfer, 2014). First, H' was calculated for the original data, H'_{all} using equation 2. Second, one of the n samples (i^{th} sample, $i = 1, 2, \ldots, n$; $n = 21$) was removed from the original dataset and the Shannon index $(\widehat{H}_i)$ was recalculated using the data from the remaining *n-1* samples. The *Jackknife* pseudo-value $(\widetilde{H}_i)$ was calculated for this data subset using the following equation: $\widetilde{H}_i = n \cdot H_{all} - (n-1) \cdot \widehat{H}_i$. This process was repeated until the pseudo-values were calculated for all n possible omissions of samples. The pseudo-values $(\widetilde{H}_i)$ were submitted to the *Kruskal-Wallis* test. Significant differences were analyzed using *Nemenyi* multiple comparison tests ($P < 0.05$). Significant for each Jaccard index was analyzed using *Chi-square* (X^2) tests ($P < 0.05$) (Zar 2010). Environmental variables and mite abundance were correlated using the Spearman method. The R Core Team software (2018) was used for all analysis.

Results

Biodiversity

A total of 47 mites species were identified associated with *C. annuum* L. var. *glabriusculum* (Table 1). The species with the highest proportion at the three sites were: *Aculops lycopersici* (Tryon), *Pseudopronematulus* sp. 4 and *Tetranychus merganser* Boudreaux, with 79.919%, 9.311%, and 5.142%, respectively (Table 1). Regarding feeding habits at the three sites (OA, AC, and CP), the highest abundances were observed for the phytophagous *A. lycopersici*, the predator *Pseudopronematulus* sp. 4, and for the generalists *Tydeus munsteri* Meyer & Ryke (0.228%), *Tyrophagus* sp. (0.419%) and *Rhizoglyphus* sp. (0.560%).

TABLE 1. Abundance and feeding habit of mites associated to *Capsicum annuum* L. var *glabrisuculum* in two Protected Natural Areas of Tamaulipas, Mexico.

Family	Species	Mites abundance (%)				Total
		ANP	El Cielo	Altas Cumbres		
		FH	OA	AC	CP	
Bdellidae	*Spinibdella* sp.	Pr	0.006		0.006	0.012
Cunaxidae	*Pulaeus* sp.	Pr	0.006			0.006
Triophtydeidae	*Triophtydeus immanis*	Pr	0.037	0.031	0.025	0.092
	Brachytydeus formosa	Ge		0.296	0.283	0.579
	Brachytydeus tuttlei	Ge		0.006	0.012	0.018
	Neolorrya boycei	Ge	0.012	0.086		0.099
Tydeidae	*Pseudolorrya nicaraguensis*	Ge		0.006	0.012	0.018
	Tydeus kochi	Ge		0.006		0.006
	Tydeus mali	Ge	0.006			0.006
	Tydeus munsteri	Ge	0.228	0.099		0.326
	Pseudopronematulus sp. 1	Pr			0.018	0.018
	Pseudopronematulus sp. 2	Pr	0.160	0.037	0.043	0.240
Iolinidae	*Pseudopronematulus* sp. 3	Pr	0.018	0.086	0.043	0.148
	Pseudopronematulus sp. 4	Pr	2.063	2.389	4.859	9.311
	Pseudopronematulus sp. 5	Pr			0.018	0.018
Eriophyidae	*Aculops lycopersici*	Ph	21.467	29.829	28.622	79.919
Anystidae	*Walzia* sp.	Pr	0.031		0.006	0.037
	Balaustioides sp.	Pr		0.006		0.006
Erythraeidae	*Erythraeus* sp.	Pr			0.018	0.018
	Leptus (Leptus) sp.	Pr			0.012	0.012
Microtrombidiidae	sp.	Pr	0.012			0.012
	Cheletogene waitei	Pr		0.006		0.006
Cheyletidae	*Chiapacheylus sp.*	Pr			0.006	0.006
	Cheletomimus dousetosus	Pr	0.012		0.006	0.018

......continued on the next page

TABLE 1.(Continued)

Family	Species	Mites abundance (%)				
		ANP	El Cielo	Altas Cumbres		Total
		FH	OA	AC	CP	
Stigmaeidae	*Agistemus* sp. nov. 1	Pr	0.080			0.080
	Agistemus sp. nov. 2	Pr			0.080	0.080
	Gymnostigmaeus sp.	Pr	0.006			0.006
Tenuipalpidae	*Brevipalpus physalis*	Ph		0.018		0.018
	Brevipalpus aepi	Ph			0.006	0.006
Tetranychidae	*Tetranychus merganser*	Ph	0.228	3.473	1.441	5.142
Tarsonemidae	*Hemitarsonemus* sp.	Ph		0.006		0.006
	Tarsonemus (Tarsonomus) sp.	Ge	0.012	0.117	0.333	0.462
Phytoseiidae	*Phytoseius mexicanus*	Pr		0.031		0.031
	Phytoseius palidus	Pr			0.012	0.012
	Amblyseius similoides	Pr	0.536		0.277	0.813
	Amblyseius coffeae	Pr		0.018		0.018
	Euseius mesembrinus	Pr		0.055	0.068	0.123
	Euseius sp.	Pr		0.012		0.012
	Metaseiulus (Metaseiulus) negundinis	Pr		0.985	0.018	1.004
	Galendromus (Galendromus) annectens	Pr			0.012	0.012
	Typhlodromalus aripo	Pr			0.006	0.006
	Proprioseiopsis reventus	Pr		0.006		0.006
Ascidae	*Asca quinta*	Pr	0.037			0.037
Blattisociidae	*Blattisocius* sp.	Pr			0.006	0.006
Acaridae	*Rhizoglyphus* sp.	Ge	0.197		0.560	0.757
	Tyrophagus sp.	Ge		0.419		0.419
	sp.	Ge			0.006	0.006

*Pr = predator; Ph = phytophagous and Ge = generalist (fungivores, scavengers or feeders on plant exudates and pollens) mites.

A total of 18 families of mites were found associated to *C. annuum* L. var. *glabriusculum*, distributed according to your feeding habits in 12 predators, 4 phytophagous and 3 generalists. The family Tarsonemidae presented two feeding habits: phytophagous (*Hemitarsonemus* sp.) and generalist (*Tarsonemus (Tarsonemus)* sp.). The highest richness related to feeding habits belong to the Phytoseiidae family (predators), with 10 species (2%), Tydeidae family (generalists), with 7 species (1%), and Tenuipalpidae family, with 2 species (phytophagous <1%). CP had the highest species richness, with 15% (29 species), as well as predators (20 species). On the other hand, the highest proportion of phytophagous mites was observed in AC, with 4 species (88%) and 8 generalists (3%).

Mite diversity did not differ among the three sites ($X^2 = 1.626$, gl = 2, $P = 0.443$) (Table 2). Regarding predators, phytophagous and generalist diversity was significantly different among sites ($X^2 = 52.862$, gl = 2, $P = 3.319e^{-12}$; $X^2 = 8.671$, gl = 2, $P = 0.013$; $X^2 = 42.322$, gl = 2, $P = 6.457e^{-10}$, respectively). Higher diversity of predatory mites ($H' = 0.65$) was observed in OA. Phytophagous diversity in OA, on the other hand, was significantly different from AC; however, mite diversity in the CP did not differ from the other sites. Generalist mite diversity was statistically equal ($P > 0.05$)

in AC and CP belonging to the same PNA "Altas Cumbres" and different in the "El Cielo" Biosphere Reserve.

Jaccard similarity indices between OA–AC, CP–AC and CP–OA were 0.257 ($X^2 = 0.568$, gl = 1, $P < 0.05$), 0.293 ($X^2 = 0.301$, gl = 1, $P < 0.05$) and 0.324 ($X^2 = 1.306$, gl = 1, $P < 0.05$), respectively. These findings indicate that there are no sites with zero similarity, which means that they share at least one species. (Table 2).

TABLE 2. Mite diversity on *Capsicum annuum* var. *glabriusculum* in Ojo de Agua, Altas Cumbres and Cañón de la Peregrina, Tamaulipas, Mexico.

Shannon Index (*H'*)								
Feeding habit	Pr		Ph		Ge		Total	
Site	$H'^{\S}$	$H'^{\Psi}\pm SD$	$H'^{\S}$	$H'^{\Psi}\pm SD$	$H'^{\S}$	$H'^{\Psi}\pm SD$	$H'^{\S}$	$H'^{\Psi}\pm SD$
Ojo de Agua (OA)	0.38	0.65±0.08^{A}	0.18	0.58±0.21^{a}	0.09	1.69±0.02^{X}	0.65	1.09±0.14^{x}
Altas Cumbres (AC)	0.32	0.54±0.04^{C}	0.41	0.63±0.12^{b}	0.14	0.25±0.03^{Y}	0.88	1.08±0.08^{x}
Cañón de la Peregrina (CP)	0.38	0.61±0.04^{B}	0.32	0.47±0.15^{ab}	0.15	0.27±0.02^{Y}	0.86	1.11±0.06^{x}
All Sites	0.39	0.64±0.03^{H}	0.33	0.50±0.16^{I}	0.15	0.25±0.04^{I}	0.86	
Jaccard Index (I_J)			OA–AC	X_i^2	CP–OA	X_i^2	AC–CP	X_i^2
			0.26	0.568*	0.32	1.306*	0.29	0.301*

§ Shannon index with complete data; $^{\Psi}$ Shannon index and standard deviation using the Jackknife method. Indices with the same letter are not significantly different (Nemenyi test, $P \leq 0.05$); NS = not significant; significance code: * < 0.05 (Chi-square test, $P < 0.05$).

Mite abundance was correlated with environmental variables in CP ($P < 0.05$), but not in AC and OA. Regarding feeding habit, predator abundance showed a significant correlation with maximum, minimum and average temperatures. Evaporation was only correlated with phytophagous abundance. Generalist mites did not show any significant correlation with environmental variables (Table 3).

TABLE 3. Correlation between mite abundance and environmental variables.

Correlation			Ojo de Agua	Altas Cumbres	Cañón de la Peregrina	Predatory	Phytophagous	Generalists
Maximum temperature	x	Abundance	-0.12^{NS}	0.21^{NS}	0.72*	0.57*	0.23^{NS}	0.09^{NS}
Minimum temperature	x	Abundance	-0.20^{NS}	0.13^{NS}	0.74*	0.48*	0.20^{NS}	0.20^{NS}
Average temperature	x	Abundance	-0.19^{NS}	0.20^{NS}	0.76*	0.54*	0.24^{NS}	0.14^{NS}
Ambient temperature	x	Abundance	-0.18^{NS}	0.078^{NS}	0.68*	0.41^{NS}	0.13^{NS}	0.15^{NS}
Evaporation	x	Abundance	-0.31^{NS}	0.35^{NS}	0.75*	0.41^{NS}	0.45*	-0.14^{NS}

NS = not significant; significance code: * < 0.05

Discussion

Mite density and diversity on wild populations of *C. annum* var. *glabriusculum* were observed to be higher than in different varieties cultivated under greenhouse conditions (Çobanoğlu & Kumral,

2016) and diversity loss and species abundance were closely related to change in and use of ecosystems (Teodoro *et al*. 2009). Regarding feeding habits, *A. lycopercisi* (phytophagous) and *Psedupronemtulus* sp.4 (predator) had the highest abundance. These densities in phytophagous and predatory mites are mainly due to some iolinid mites on plants, which play an important role in trophic chains. This allows the regulation of *A. lycopercisi* populations, and provides supplementary food to phytoseiid mites (Carmona 1970; Hessein & Perring 1986; Abou-Awad *et al*. 1999). The low proportion of mite species indicates they are possibly associated as alternative or occasional hosts (Castro & Moraes 2007; Nicholls 2008).

Among the most important factors that determine maximum diversity is elevation, geographical position and mountain orientation (Fischner *et al*. 2011). According to the general pattern of richness and abundance of mites, the number of species tends to decrease to a greater altitudinal gradient (Fischer & Schatz 2013; Hugo-Coetzee & Roux 2018). However, in this study the greatest diversity and abundance was obtained at the highest altitudes included in AC and CP belonging to the ANP "Altas Cumbres", also observed in oribatid mites (Oribatida), springtail (Artropoda: Collembola) and craneflies larvae (Insecta: Diptera: Tipulidae) (Coulson & Whittaker 1978; Hashemi *et al*. 2014; Hugo-Coetzee & Roux 2018). The high richness and abundance of species depends on a series of biotic and abiotic factors, where the adaptability to climate change and biology of the species makes it possible that the species of higher altitudes have the same representativeness the low altitudes (Hugo-Coetzee & Roux 2018). Observing how the environmental variables and the geography of the sites affect the abundance of predators, since they directly depend on the presence or absence of host plants that offer refuge, food and the ability to reproduce (Hodkinson 2005).

Abundance and species richness of the predatory families Bdellidae, Cheyletidae and Cunaxidae on chile piquín were not as high as in Phytoseiidae, which corroborates other studies on diversity in different ecosystems (land use types, agroforestry and semideciduous seasonal forest) (Teodoro *et al.* 2009; Maribie *et al.* 2011; Demite *et al.* 2013). This difference is believed to be due to the fact that these species are less active and are ambush predators in some cases (Muma 1975). Similar to our findings, Cruz *et al*. (2013) and Singh & Chauhan (2014) found that generalist predators of the Phytoseiidae family are more abundant in stable ecosystems and have higher diversity compared to other Mesostigmata groups. Eight generalist predatory species and two specialists were recorded. PNA provide a wide variety of food, such as phytophagous mites, pollen and insects, reflecting the level of ecosystem conservation and their stability in face of anthropogenic disturbance (McMurtry 1992; McMurtry & Croft 1997; Maleque *et al*. 2006), and each species has specific climatic adaptations, which allows them to better adapt to their habitats (Knop & Hoy 1983; James & Taylor 1992).

The three sites did not share the same species number; therefore, the similarity *Jaccard* index among sites was low. This is mainly because each site has a different mite species richness, which in turn is associated with the type of vegetation and climate. However, a higher predatory mite diversity was observed than phytophagous and generalist mite diversity at all sites. The highest number of mites was recorded in the group of generalist predators, since they are not directly associated with the host plant, and depend on resources that the plant can provide to a greater extent, such as the variety of prey and supplementary food "pollen" (Gardiner *et al*. 2009; Cruz *et al*. 2013; McMurtry *et al*. 2013; Araújo & Daus 2018). As opposed to phytophagous mites, they are usually highly specific (Saito 2010), e.g. *A. lycopercisi* and *T. merganser*. The latter and *T. hydrangea* Pritchard & Baker have been reported in cultivated varieties of *C. annuum* at México (Estebanes-Gonzales & Rodriguez-Navarro 1991). Mite behavior and richness at three sites suggest that flora diversity in PNA directly affect mite community structure (Root 1973; Welti *et al*. 2017).

Environmental variables were correlated with mite abundance in CP and with predatory mites. Among environmental factors, temperature directly and crucially affects vital processes for mite survival, development and movement (Skirvin & Fenlon 2003; Mirhosseini *et al.* 2017). The threshold between maximum, minimum temperatures and optimal temperature should be considered in the biological performance of predators, since, any change in temperature within a specific range results in a proportional increase or decrease in rate of any life process (Roy *et al.* 2002; Al-Shammary 2011). On the other hand, ambient temperature was not correlated with mite abundance in OA and AC, possibly because leaf temperature can vary considerably according to temperature in the environment and is slightly cooler due to evapotranspiration. Therefore, temperature should not be considered due to the effect of moisture on small arthropods such as mites (Ferro & Southwick 1984; Weintraub *et al.* 2007). Spearman's method indicated that evaporation plays an important role in the abundance of phytophagous mites. Evaporation increases phytophagous mite populations when plants undergo water stress (Van Leeuwen *et al.* 2010).

The presence of domatia and trichomes was observed in leaves of *C. annuum* var. *glabriusculum* in the axillary bud of the midrib on the abaxial side of the leaf, which provides shelter and suitable microhabitats (Walter 1996; Situngu & Barker 2017) for families Cheyletidae, Cunaxidae, Tydeidae, Iolinidae, Triophtydeidae, Stigmaeidae, Phytoseiidae, Ascidae and Acaridae. Leaf structure possibly helps to increase mite species richness in chile piquín, unlike species abundance of *Phytoseius mexicanus* De Leon and *P. paludis* De Leon, which was low. These two species are mainly confined to pubescent leaves, a characteristic that does not occur on leaves of chile piquín (Walter 1996). Plant morphology, as well as its phenotypic variability among populations, serves as hosts for predators in management strategies and conservation of natural enemies (Halaj *et al.* 2000; Schmidt 2014).

In this study, 14 new records are reported in Mexico: *Balaustoides* sp., Microtrombidiidae, *Brachytydeus mali* Oudemans, *B. tuttlei* Baker, *Pseudolorrya nicaraguensis* Baker, *Tydeus kochi* Oudemans, *T. munsteri* Meyer & Ryke, *Cheletogenes waitei* Gerson, *Gymnostigmaeus* sp., *Hemitarsonemus* sp., *Pseudopronematulus* spp., *Triophtydeus immanis* Kuznetzov, *Walzia sp.* and *Proprioseiopsis reventus* Zack. Our results recognize the importance of preserving plant species that serve as a reservoir and directly affect mite fauna hosts, allowing for a large network of trophic interactions. The large number of mite species associated to chile piquín suggests stability in PNA despite anthropogenic activities. Therefore, Protected Natural Areas shelter a high predatory mite diversity and the use of natural resources such as chile piquín and other species of ecological importance can be considered in conservation programs.

Acknowledgment

The authors thank Universidad Autónoma de Tamaulipas for supporting this research through projects PFI2016-EB07, Universidade do Vale do Taquari – Univates for the opportunity to carry out the identification of mites in this study, and Universidade Federal do Rio Grande do Sul and CONACyT for supporting this research.

References

Abou-Awad, B.A., El-Sawaf, B.M. & Abdel-Kader, A.A. (1999) Life history and life table of *Pronematus ubiquitus* (McGregor) as a predator of eriophyoid mites in Egypt (Acari: Tydeidae). *Acarologia*, 40(1), 29–32.

Acuña-Soto, J.A., Estrada-Venegas, E.G. & Equihua-Martinez, A. (2015) Diversidad de ácaros eriófidos (Prostigmata: Eriophyoidea), en palmeras (Arecaceae) de México. *Entomología Mexicana*, 2, 94–99.

Acuña-Soto, J.A., Estrada-Venegas, E.G., Equihua-Martínez, A., Vázquez-Rojas, I.M., Romero-Napoles, J., Rodríguez-Ortega, A. & Otero-Colina, G. (2017) Nuevos Registros de Ácaros Eriófidos Asociados a Tres

Familias de Árboles Forestales en México. *Southwestern Entomologist*, 42, 493–512. https://doi.org/10.3958/059.042.0219

Aguilar, H. & P. Murillo. (2012) Nuevos hospederos y registros de ácaros fitófagos para Costa Rica: período 2008-2012. *Agronomía Costarricense*, 36(2), 11–28.

Aguirre-Hernández, E., San Miguel-Chávez, R., Palma-Tenango, M., González-Trujano, M.E., Medina-Martínez, T., Sánchez-Ramos, G., Mora-Olivo, A., Martínez-Palacios, A. & Martínez-Ávalos, J.G. (2017) Capsaicinoids concentration in *C. annuum* var. *glabriusculum* collected in Tamaulipas, Mexico. *Phyton, International Journal of Experimental Botany*, 86, 46–52

Al-Shammary, K.A. (2011) Effect of Temperature on the Biology and Life Tables of *Agistemus exsertus* Fed *Tetranychus urticae* (Acari: Stigmaeidae: Tetranychidae) in Hail, Saudi Arabia. *Journal of Entomology*, 8, 557–565. http://dx.doi.org/10.3923/je.2011.557.565

André, H.M. (1980) A generic revision of the family Tydeidae (Acari: Actinedida). IV. Generic descriptions, keys and conclusion. *Annales de la Societe royale Zoologique* de Belgie, 116, 103–168.

Araújo, W.S. & Daud, R.D. (2018) Contrasting structures of plant-mite networks compounded by phytophagous and predatory mite species. *Experimental & Applied Acarology*, 74(4), 335–346. https://doi.org/10.1007/s10493-018-0250-2

Badii, M.H., Flores, A.E., Ponce, G., Landeros, J., Quiroz, H. (2001) Does the *Lorryia formosa* population visit or reside on citrus foliage? *In*: Halliday, R.B., Walter, D.E., Proctor, H.C., Norton, R.A., Colloff, M.J., (eds). Acarology: proceedings of the 10th International Congress. Melbourne: CSIRO Publishing, pp. 413–448.

Baker, E.W. & Tuttle, D.M. (1987) The False Spider Mites of Mexico (Tenuipalpidae: Acari). U.S. Department of Agriculture, Technical Bulletin No. 1706, 237 pp.

Barker, E.W. & Tuttle, D.M. (1994) A Guide to the Spider Mites (Tetranychidae) of the United States. Indira Publishing House, West Bloomfield, MI. 346 pp.

Bautista, Z.F., Delfín, H. & Palacios, J.L. (2011) Técnicas de muestreo para manejadores de recursos naturales. Universidad Nacional Autónoma de México, 770 pp.

Bucio-Soto, G., Ayala-Ortega, J. de J., Vargas-Sandoval, M., Lara-Chávez Ma. B.N., Aguirre-Paleo, S. & Negrete-Rodríguez, O.M. (2016) Acarofauna asociada al cultivo del arándano (*Vaccinium corymbosum* L. var. *biloxi*) en Ziracuaretiro, Michoacán. *Entomología mexicana*, 3, 120–124.

Carmona, M.A. (1970) Contribuição para o conhecimento dos ácaros de plantas cultivadas em Portugal. *V Agronomia Lusit*, 31, 137–183

Castro, T.M.M.G. & de Moraes, G.J. (2007) Mite diversity on plants on different families found in the Brazilian Atlantic Forest. *Neotropical Entomology*, 36(5), 774−782. https://doi.org/10.1590/S1519-566X2007000500020

Castro, T.M.M.G. & Den Heyer, J. (2009) A revision of the genus *Pulaeus* Den Heyer with descriptions of a new genus and four new Brazilian species (Acari: Prostigmata: Cunaxidae). *Zootaxa*, 2141, 20–36. https://doi.org/10.11646/zootaxa.2141.1.2

Chant, D.A. & McMurtry, J.A. (2007) Illustrated keys and diagnoses for the genera and sub-genera of the Phytoseiidae of the World. Indira Publishing House, West Bloomfield, Michigan, 220 pp.

Çobanoğlu, S. & Kumral, N. A. (2016) The biodiversity, density and population trend of mites (Acari) on *Capsicum annuum* L. in temperate and semi-arid zones of Turkey. *Systematic & Applied Acarology*, 21(7), 907–918. https://doi.org/10.11158/saa.21.7.5

Coulson, J.C. & Whittaker, J.B. (1978) Ecology of moorland animals. *In:* Heal, O.W. & Perkins, D.F. (eds.). *Production Ecology of British Moors and Montane Grasslands*. Berlin, SpringerVerlag, pp. 52–93. https://doi.org/10.1007/978-3-642-66760-2_4

Cruz, W.P., Sarmento, R.A., Teodoro, A.V., Neto M.P. & Ignácio, M. (2013) Driving factors of the communities of phytophagous and predatory mites in a physic nut plantation and spontaneous plants associated. *Experimental & Applied Acarology*, 60(4), 509–519. https://doi.org/10.1007/s10493-013-9663-0

Demite, P.R., Lofego, A.C. & Feres, R.J.F. (2013) Mite (Acari; Arachnida) diversity of two native plants in fragments of a semideciduous seasonal forest in Brazil. *Systematics and Biodiversity*, 11(2), 141–148. https://doi.org/10.1080/14772000.2013.806368

Dhooria, M.S. (2016). Acarine tecnology. *In*: Dhooria, M.S. (ed.) *Fundamentals of Applied Acarology.* Singapure. Springer, 470 pp.

Dirzo, R. (1992) Diversidad florística y estado de conservación de las selvas tropicales de México. *In*: Sarukhan, J. & R. Dirzo (Eds.). México ante los retos de la biodiversidad. CONABIO, México, D.F. pp. 283–290

Ehara, S. & Ueckermann, E.A. (2006) A new genus of Stigmaeidae (Acari: Prostigmata) from Okinawa Island. Zootaxa, 1160, 29–36.
https://doi.org/10.11646/zootaxa.1160.1.3

Estebanes-Gonzalez, M.L. & Rodriguez-Navarro, S. (1991) Observaciones sobre algunos ácaros de las Familias Tetranychidae, Eriophyidae, Acaridae y Tarsonemidae (Acari), en México. *Folia Entomologica Mexicana*. 83, 199–212.

Fan, Q. & Li, L. 1992. new genus and three new species of Tydeidae (Acari: Actinedida) from China. *Journal of Fujian Agricultural College*, 21, 396–400. (Chi).

Fan, Q.H., Flechtmann, C.H.W. & de Moraes, G.J. (2016) Annotated catalogue of Stigmaeidae (Acari: Prostigmata), with a pictorial key to genera. *Zootaxa*, 4176, 1–199.
http://doi.org/10.11646/zootaxa.4176.1.1

Ferro, I. & Morrone, J.J. (2014) Biogeographic transition zones: a search for conceptual synthesis. *Biological Journal of the Linnean Society*. 113, 1–12.
https://doi.org/10.1111/bij.12333

Ferro, D.N. & Southwick, E.E. (1984) Microclimates of small arthropods: estimating humidity within the leaf boundary layer. *Environmental Entomology*, 13(4), 926–929.
https://doi.org/10.1093/ee/13.4.926

Fischer, B.M. & Schatz, H. (2013) Biodiversity of oribatid mites (Acari: Oribatida) along an altitudinal gradient in the Central Alps. *Zootaxa*, 3626, 429–454.
https://doi.org/10.11646/zootaxa.3626.4.2

Fischer, A., Blaschke, M. & Bässler, C. (2011) Altitudinal gradients in biodiversity research: the state of the art and future perspectives under climate change aspects. *Waldökologie, Landschaftsforschung und Naturschutz*, 11, 35–47.

Friedl, H. & Stampfer, E. (2014) Jackknife resampling. *In:* Wiley StatsRef. Statistics Reference Online, Wiley.

Gardiner, M.M., Landis, D.A., Gratton, C., Difonzo C.D., O'neal, M., Chacon, J.M., Wayo, M.T., Schmidt, N.P., Mueller, E.E. & Heimpel, G.E. (2009) Landscape diversity enhances biological control of an introduced crop pest in the north-central USA. *Ecological Applications*, 19, 143–154.
https://doi.org/10.1890/07-1265.1

Gerson, U., Fain, A. & Smiley, R.L. (1999) Further observations on the Cheyletidae (Acari), with a key to the genera of the Cheyletinae and a list of all known species in the family. *Bulletin de Institut royal des Sciences Naturelles de Belgique. Entomologie*, 69, 35–68.

González-Ocampo, H.A., Rodríguez-Quiroz, G. & Ortega-Rubio, A. 2015. Una Revisión de las Áreas Naturales Protegidas de México. *In*: Ortega-Rubio, A., Pinkus-Rendón & Espitia-Moreno, I. (eds.) *Las Áreas Naturales Protegidas y la Investigación Científica en México*. Centro de Investigaciones Biológicas del Noreste S. C., La Paz B. C. S., Universidad Autónoma de Yucatán, Mérida, Yucatán y Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán, México, pp. 19–40

Halaj, J., Ross, D.W. & Moldenke, A.R. (2000) Importance of habitat structure to the arthropod food-web in Douglas-fir canopies. *Oikos*, 90, 139–152.
https://doi.org/10.1034/j.1600-0706.2000.900114.x

Hashemi, K.Z., Irani, N.K.H., Moghaddam, M., Khanjani, M. & Reza, Z.M. (2014) Species richness of oribatid mites (Acari: Oribatida) in rangelands of West Azerbaijan province, Iran. *Persian Journal of Acarology*, 3, 293–309.
http://dx.doi.org/10.22073/pja.v3i4.10179

Hayano-Kanashiro, C., Gámez-Meza, N., & Medina-Juárez, L.Á. (2016) Wild Pepper *Capsicum annuum* L. var. *glabriusculum*: Taxonomy, Plant Morphology, Distribution, Genetic Diversity, Genome Sequencing, and Phytochemical Compounds. *Crop Science*, 56, 1–11.
https://doi.org/ 10.2135/cropsci2014.11.0789

Hernandes, F.A., Skvarla, M.J., Fisher, J.R., Dowling, A.P.G., Ochoa, R., Ueckermann, E.A. & Bauchan, G.R. (2016) Catalogue of snout mites (Acariformes: Bdellidae) of the world. *Zootaxa*, 4152(1), 1–83.
http://doi.org/10.11646/zootaxa.4152.1.1

Hernández, S.L., González, R.C.E. & González, M.F. (1991) Plantas útiles de Tamaulipas. *Anales del Instituto* *de Biología, Serie Botánica*, 62, 1–38.

Herrera-Izaguirre, J.A., Lope-Díaz, L.H., García-Govea, M., Manguin-Guixeras, V. & Escobedo-Carreón, R.A. (2014) Áreas Naturales Protegidas en el Estado de Tamaulipas: ¿Por Quién están Protegidas?. *Revista Científica Biológico Agropecuaria Tuxpan*, 2(2), 111–116

Hessein, N.A. & Perring, T.M. (1986) Feeding habits of the Tydeidae with evidence of *Homeopronematus anconai* (Acari: Tydeidae) predation of *Aculops lycopersici* (Acari: Eriophyidae). *International Journal of Acarology*, 12, 215–221
https://doi.org/10.1080/01647958608683467

Hodkinson, I.A. (2005) Terrestrial insects along elevation gradients: species and community responses to altitude. *Biological Reviews*, 80, 489–513.
https://doi.org/10.1017/S1464793105006767

Hoffman, A. & López-Campos, G. (2002) Acari. *In*: J. Llorente Bousquets y J.J. Morrone (eds.), Biodiversidad, taxonomía y biogeografía de Artrópodos de México, Hacia una síntesis de su conocimiento. Vol. 3. UNAM, Mexico, D.F. pp 223–276.

Hugo-Coetzee, E.A. & Le Roux, P.C. (2018) Distribution of microarthropods across altitude and aspect in the sub-Antarctic: climate change implications for an isolated oceanic island. *Acarologia*, 58(Suppl), 43–60. https://doi.org/10.24349/acarologia/20184278

Iñiguez, D.L.I., Jiménez, S.C.L., Sosa, R.J. & Ortega-Rubio, A. (2014) Categorías de las Áreas Naturales Protegidas en México y una propuesta para la evaluación de su efectividad. *Investigación y Ciencia de la Universidad Autónoma de Aguascalientes*, 60, 65–70.

James, D.G. & Taylor, A. (1992) Effect of temperature on development and survival of *Amblyseius victoriensis* (Womersley) (Acari: Phytoseiidae). *International Journal of Acarology*, 18(2), 93–96.
https://doi.org/10.1080/01647959208683938

Kamran, M. & Alatawi, F.J. (2014) Erythraeid mites (Prostigmata, Erythraeidae) from Saudi Arabia, description of three new species and a new record. *ZooKeys*, 445, 77–95.
https://doi.org/10.3897/zookeys.445.7861

Knop, N.F. & Hoy, MA. (1983) Biology of a tydeid mite, *Homeopronematus anconai* (n. comb.) (Acari: Tydeidae), important in San Joaquin Valley vineyards. *Hilgardia*, 51, 1–30.
https://doi.org/10.3733/hilg.v51n05p030

Kraft, K.H., Luna-Ruíz, J.J. & Gepts, P. (2013) A new collection of wild populations of Capsicum in Mexico and the southern United States. *Genetic Resources and Crop Evolution*, 60(1), 225–232.
https://doi.org/10.1007/s10722-012-9827-5

Krantz, G.W. & Walter, D.E. (2009) *A manual of acarology. Third Edition*. Texas Tech University Press, Lubbock, Texas, 807 pp.

Landis, D.A., Wratten, S.D. & Gurr, G.M. (2000) Habitat management to conserve natural enemies of arthropod pests in agriculture. *Annual Review Entomology*, 45, 175–201.
https://doi.org/10.1146/annurev.ento.45.1.175

Leiva, S. Fernandez, N., Theron, P. & Rollard, C. (2013) *Agistemus aimogastaensis* sp. n. (Acari, Actinedida, Stigmaeidae), a recently discovered predator of eriophyid mites *Aceria oleae* and *Oxycenus maxwelli*, in olive orchards in Argentina. *ZooKeys*, 312, 65–78.
https://doi.org/10.3897/zookeys.312.5520

Llorente-Bousquets, J. & Morrone, J.J. (2002) Biodiversidad, taxonomía y biogeografía de artrópodos de México: Hacia una síntesis de su conocimiento, Vol. III. Facultad de Ciencias, UNAM, Mexico, D.F., 690 pp.

Magurran, A.E. (2004) Measuring Biological Diversity. Oxford, Blackwell Publishing, 107 pp.

Maleque, M.A., Ishii, H.T. & Maeto, K. (2006) The Use of Arthropods as Indicators of Ecosystem Integrity in Forest Management. *Journal of Forestry*, 104(3), 113–117.
https://doi.org/10.1093/jof/104.3.113

Maribie, C.W., Nyamasyo, G.H.N., Ndegwa1, P.N., Mung'atu, J.K., Lagerlöf, J. & Gikungu, M. (2011) Abundance and diversity of soil mites (Acari) along a gradient of land use types in Taita Taveta, Kenya. *Tropical and Subtropical Agroecosystems,* 13(1), 11–26.

McMurtry, J.A. & Croft, B.A. (1997) Life-styles of phytoseiid mites and their roles in biological control. *Annual Review of Entomology*, 42, 291–321.
https://doi.org/10.1146/annurev.ento.42.1.291

McMurtry, J.A., Moraes, G.J. & Sourassou, N.F. (2013) Revision of the lifestyles of phytoseiid mites (Acari: Phytoseiidae) and implications for biological control strategies. *Systematic & Applied Acarology*, 18(4),

297–320.
https://doi.org/10.11158/saa.18.4.1

McMurtry, J.A. (1992) Dynamics and potential impact of "generalist" phytoseiids in agroecosystems and possibilities for establishment of exotic species. *Experimental & Applied Acarology*, 14(4), 371–382.
https://doi.org/10.11158/saa.18.4.1

Mejía-Recamier, B.E. & Palacios-Vargas, J.G. (2018) Ácaros cunáxidos (Prostigmata) asociados a la canopia de la selva alta perennifolia de los Tuxtlas, Veracruz. *Entomología Mexicana*, 5, 58–63.

Meyer, M.K.P.S. & Ueckermann, E.A. (1987) A taxonomic study of some Anystidae (Acari: Prostigmata). Entomology Memoir, Department of Agriculture and Water Supply Sa. Afr, No. 68.

Migeon, A. & Dorkeld, F. (2019) Spider Mites Web: a comprehensive database for the Tetranychidae. Availabe from http://www.montpellier.inra.fr/CBGP/spmweb (Accessed 10/06/2019)

Mireles-Rodríguez, E., Moctezuma-Balderas, N.L., Castro-Nava, S., Salazar-Hernández, R., Lucio-Castillo, H. & Pérez-Jasso, C. 2015. *Acta Agricola y Pecuaria*, 1(3), 99–106.

Mirhosseini, M.A., Fathipour, Y. & Reddy, G.V.P. (2017) Arthropod Development's Response to Temperature: A Review and New Software for Modeling. *Annals of the Entomological Society of America*, 110(6), 507–520.
https://doi.org/10.1093/aesa/sax071

Moraes, G.J.D., McMurtry, J.A., Denmark, H.A. & Campos, C.B. (2004) A revised catalog of the mite family Phytoseiidae. *Zootaxa*, 434, 1–494.
https://doi.org/10.11646/zootaxa.434.1.1

Moraes, G.J., Britto, E.P.J., Mineiro, J.L. de C. & Halliday, B. (2016) Catalogue of the mite families Ascidae Voigts & Oudemans, Blattisociidae Garman and Melicharidae Hirschmann (Acaria: Mesostigmata). *Zootaxa*, 4112(1), 1–299.
https://doi.org/10.11646/zootaxa.4112.1.1

Morrone, J.J. (2005) Hacia una síntesis biogeográfica de México. *Revista Mexicana de Biodiversidad*, 76(2), 207–252.
https://doi.org/10.22201/ib.20078706e.2005.002.303

Muma, M.H. (1975) *Mites associated with Citrus in Florida*. Agricultural Experimental Station, University of Florid Bulletin, 640 pp.

Rehman, M.U., Kamran, M. & Alatawi, F.J. (2018) Genus *Agistemus* Summers (Acari: Trombidiformes: Stigmaeidae) from Saudi Arabia and a key to the world species. *Systematic and Applied Acarology*, 23(6),1051–1072.
https://doi.org/10.11158/saa.23.6.5

Nicholls, E.C.I. (2008) Control biológico de insectos: un enfoque agroecológico. Medellín, Editorial Universidad de Antioquia, 282 pp.

Ojeda, M., Rivas, G. & Álvarez, F. (2016) First record of the genus *Limnohalacarus* (Acari: Halacaridae) from Mexico. *Revista Mexicana de Biodiversidad*, 87, 1131–1137.
http://dx.doi.org/10.1016/j.rmb.2016.06.016

Páez, J., Villagomez, F. & Palacios-Vargas, J.G. (2019) Description of a new *Pergalumna* (Acari: Oribatida: Galumnidae) species from Mexico and its postembryonic development. *Zootaxa*, 4647, 385–406.
https://doi.org/10.11646/zootaxa.4647.1.25

Paredes-León, R., Corona-López, A.M., Flores-Palacios, A. & Toledo-Hernández, V.H. (2016) Camerobiid mites (Acariformes: Raphignathina: Camerobiidae) inhabiting epiphytic bromeliads and soil litter of tropical dry forest with analysis of setal homology in the genus *Neophyllobius*. *European Journal of Taxonomy*, 202, 1–25.
https://doi.org/10.5852/ejt.2016.202

Pérez, T.M., Guzmán-Cornejo, C., Montiel-Parra, G., Paredes-León, R. & Rivas, G. (2014) Biodiversidad de ácaros en México. *Revista Mexicana de Biodiversidad*, *Supl*. 85, S399–S407.
https://doi.org/10.7550/rmb.36160

R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Ramírez-Novoa, U., Cervantes-Ortiz, F., Montes-Hernández, S., Raya-Pérez, J., Cibrián-Jaramillo, A. & Andrio-Enriquez, E. (2018) Diversidad morfológica del chile piquín (*Capsicum annuum* L. var. *glabriusculum*) de Querétaro y Guanajuato, México. *Revista Mexicana De Ciencias Agrícolas*, 9, 1159–1172. https://doi.org/https://doi.org/10.29312/remexca.v9i6.1581

Root, R.B. (1973). Organization of a Plant-arthropod association in simple and diverse habitats: the fauna of collards (Brassica Oleracea). *Ecological Monographs*, 43(1), 95–124. https://doi.org/10.2307/1942161

Roy, M., Brodeur, J. & Cloutier, C. (2002) Relationship between temperature and developmental rate of *Stethorus punctillum* (Coleoptera: Coccinellidae) and its prey *Tetranychus mcdanieli* (Acarina: Tetranychidae). *Enviromental Entomology*, 31(1), 177–187. https://doi.org/10.1603/0046-225X-31.1.177

Ruíz-Cancino, E. & Coronado, J.M. (2002) Artrópodos terrestres de los estados de Tamaulipas y Nuevo León, México. Ciudad Victoria: Serie Publicaciones Científicas, CIDAFF-UAT, No. 4. Tamaulipas, Ciudad Victoria, 377 pp.

Saito, Y. (2010) *Plant mites and sociality: diversity and evolution*. New York, Springer, pp. 5–38.

Schmidt, R.A. (2014) Leaf structures affect predatory mites (Acari: Phytoseiidae) and biological control: a review. *Experimental & Applied Acarology*, 62(1), 1–17. https://doi.org/10.1007/s10493-013-9730-6

Skvarla, M.J., Fisher, J.R. & Dowling, A.P.G. (2014) A review of Cunaxidae (Acariformes, Trombidiformes): Histories and diagnoses of subfamilies and genera, keys to world species, and some new locality records. *ZooKeys*, 418, 1–103. http://doi.org/10.3897/zookeys.418.7629

Silva, G.L., Silva, C.U. & Ferla, N.F. (2014) Life cycle of *Tydeus californicus* (Acari: Tydeidae) on leaves of *Inga marginata* with and without pollen of *Typha angustifolia* under laboratory conditions. *International Journal of Acarology*, 40(7), 509−512. https://doi.org/10.1080/01647954.2014.953999

Silva, G.L., Metzelthin, M. Silva, O.S. & Ferla, N.J. (2016) Catalogue of the mite family Tydeidae (Acari: Prostigmata) with the world key to the species. *Zootaxa*, 4135, 1–68. http://doi.org/10.11646/zootaxa.4135.1.1

Silva, G.L., Da-Costa, T., Ferraz, C.S., Pallini, Â. & Ferla, N.J. (2017). First description of iolinid mites (Acari: Tydeoidea) from Brazil. *Systematic and Applied Acarology*, 22(5), 694–701. https://doi.org/10.11158/saa.22.5.8

Singh, V. & Chauhan, U. (2014) Diversity of mite (Acari) fauna associated with vegetables and ornamental plants in mid-hill conditions of Himachal Pradesh, India. *Journal of Biological Control*, 28(2), 18–23. https://doi.org/10.18311/jbc/2014/3243

Situngu, S. & Barker, N.P. (2017) Position, position, position: Mites occupying leaf domatia are not uniformly distributed in the tree canopy. *South African Journal of Botany*, 108, 23–28. https://doi.org/10.1016/j.sajb.2016.09.012

Skirvin, D. & Fenlon, J. (2003) Of mites and movement: the effects of plant connectedness and temperature on movement of *Phytoseiulus persimilis*. *Biological Control*, 27(3), 242–250. https://doi.org/10.1016/S1049-9644(03)00022-7

Teodoro, A.V., Klein, A.-M. & Tscharntke, T. (2009) Temporally mediated responses of the diversity of coffee mites to agroforestry management. *Journal of Applied Entomology*, 133, 659–665. https://doi.org/10.1111/j.1439-0418.2009.01422.x

Trejo-Palacios, S.J., Martínez-Salzar, E.A., Rosas-Valdez, R. & Paredes-León, R. (2019) A new species of *Morelacarus* (Acariformes: Prostigmata: Leeuwenhoekiidae) associated with *Sceloporus grammicus* (Squamata: Phrynosomatidae) from the mexican plateau, Zacatecas, Mexico. *Journal of Parasitology*, 105, 85–91. https://doi.org/ 10.1645/18-76

Ueckermann, E.A. & Grout, T.G. (2007) Tydeoid mites (Acari: Tydeidae, Edbakerellidae, Iolinidae) occurring on Citrus in southern Africa. *Journal of Natural History*, 41(37–40), 2351–2378. https://doi.org/10.1080/00222930701589921

Vázquez, M.M. & Klompen, H. (2015) The family Opilioacaridae (Parasitiformes: Opilioacarida) in Mexico, description of two new species and notes on biology and geographical distribution. *Zootaxa*, 3957, 535–552. https://doi.org/10.11646/zootaxa.3957.5.3

Vázquez-Rojas, I.M., Estrada-Venegas, E.G. & López-Campos, M.G. (2015) Mites of the families Pygmephoridae and Neopygmephoridae (Acari: Pygmephoroidea) from soils in Mexico. *Revista Mexicana de Biodiversidad*, 86, 605–612. https://doi.org/10.1016/j.rmb.2015.05.009

Villalon-Mendoza, H., Ramirez-Meraz, M., Garza-Ocanas, F. & Maiti, R. (2016) Value Chain of Chile Piquin Wild Chili (*Capsicum annuum* L. var. *glabriusculum*) from Northeastern Mexico. *International Journal of Bio-Resource & Stress Management*, 7, 455–460.
https://doi.org/10.23910/IJBSM/2016.7.3.1496b

Van Leeuwen, T., Witters, J., Nauen, R., Duso, C. & Tirry, L. (2010) The control of eriophyoid mites: state of the art and future challenges. *In*: Ueckermann, E.A. (eds.) *Eriophyoid mites: progress and prognoses*. Dordrecht, Springer, pp. 205–224.
https://doi.org/10.1007/978-90-481-9562-6_11

Villalobos, L. (2000) Áreas naturales protegidas: instrumento estratégico para la conservación de la biodiversidad. *Gaceta Ecológica*. 54: 24–34.

Walter, D.E. (1996) Living on Leaves: Mites, Tomenta, and Leaf Domatia. *Annual Review of Entomology*, 41, 101–114.
https://doi.org/ 10.1146/annurev.en.41.010196.000533

Weintraub, P.G., Kleitman, S., Alchanatis, V. & Palevsky, E. (2007) Factors affecting the distribution of a predatory mite on greenhouse sweet pepper. *Experimental & Applied Acarology*, 42, 23–35.
https://doi.org/10.1007/s10493-007-9077-y

Welti, E., Helzer, C. & Joern, A. (2017). Impacts of plant diversity on arthropod communities and plant-herbivore network architecture. *Ecosphere*, 8(10), e01983.
https://doi.org/10.1002/ecs2.1983

Zar, J.H. (2010) *Bioastatical Analysis. 5th edition*. Person Prentice Hall, New Jersey, Upper Saddle River, 944 pp.

Submitted: 25 Oct. 2019; accepted by Rostislav Zemek: 12 Nov. 2019; published: 31 Dec. 2019