Armored Scales (Hemiptera: Diaspididae) and Their Parasitoids on Hass Avocado (Persea americana Miller) in Two Municipalities of the State of Mexico, Mexico

Authors: Lázaro-Castellanos, Carlos, González-Hernández, Hector, Romero-Nápoles, Jesús, Ortega-Arenas, Laura D., Equihua-Martínez, Armando, et al.

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Armored scales (Hemiptera: Diaspididae) and their parasitoids on Hass avocado (*Persea americana* Miller) in two municipalities of the State of Mexico, Mexico

Carlos Lázaro-Castellanos[1], Hector González-Hernández[1,], Jesús Romero-Nápoles[1], Laura D. Ortega-Arenas[1], Armando Equihua-Martínez[1], and Salvador Ochoa-Ascencio[2]*

Abstract

Armored scales and their parasitoids were collected and identified from avocado orchards in 2 municipalities of the state of Mexico; the population fluctuation and parasitism of the 3 most abundant armored scales also were determined. The armored scales species (Hemiptera: Diaspididae) identified were *Hemiberlesia cyanophylli* (Signoret), *Davidsonaspis aguacatae* (Evans, Watson, & Miller), *Diaspis* nr. *coccois* (Lichtenstein), *Hemiberlesia lataniae* (Signoret), and *Hemiberlesia rapax* (Comstock); as well as the associated parasitoids *Encarsia aurantii* (Howard), *Encarsia citrina* (Craw), *Encarsia gaonae* (Myartseva & Evans), *Encarsia lounsburyi* (Berlese & Paoli), *Aphytis proclia* (Walker), *Coccobius averini* (Myartseva); *Coccobius juliae* (Myartseva), *Coccobius mariae* (Myartseva) (all Hymenoptera: Aphelinidae), *Signiphora falcata* (Woolley & Dal Molin); *Signiphora fax* (Girault), *Signiphora flavella* (Girault), *Signiphora mexicana* (Ashmead) (all Hymenoptera: Signiphoridae), and *Plagiomerus diaspidis* (Crawford) (Hymenoptera: Encyrtidae). Some species from both groups constituted new distribution or host records in Mexico. Armored scale population densities generally increased per orchard and type of avocado tree structure from Oct to Apr, depending on the phenology of the avocado trees. The percentage of parasitism and adult parasitoid emergence varied according to their armored scale host population density. Most of the parasitoids emerged from armored scales collected from branches (82), followed by armored scales collected from fruits (59), and leaves (18).

Key Words: *Hemiberlesia*; *Davidsonaspis*; population fluctuation; parasitism; Aphelinidae; Signiphoridae

Resumen

Las escamas armadas (Hemiptera: Diaspididae) y sus parasitoides se colectaron de huertos de aguacate de dos municipios del Estado de México, además, de las tres escamas armadas más abundantes se determinó la fluctuación poblacional y parasitismo. Las especies de escamas armadas identificadas fueron: *Hemiberlesia cyanophylli* (Signoret), *Davidsonaspis aguacatae* (Evans, Watson, & Miller), *Diaspis* c.a. *coccois* (Lichtenstein), *Hemiberlesia lataniae* (Signoret) y *Hemiberlesia rapax* (Comstock); así como los parasitoides *Encarsia aurantii* (Howard), *Encarsia citrina* (Craw), *Encarsia gaonae* (Myartseva & Evans), *Encarsia lounsburyi* (Berlese & Paoli), *Aphytis proclia* (Walker), *Coccobius averini* (Myartseva), *Coccobius juliae* (Myartseva), *Coccobius mariae* (Myartseva) (todos Hymenoptera: Aphelinidae); *Signiphora falcata* (Woolley & Dal Molin), *Signiphora fax* (Girault), *Signiphora flavella* (Girault), *Signiphora mexicana* (Ashmead) (todos Hynemoptera: Signiphoridae) y *Plagiomerus diaspidis* (Crawford) (Hymenoptera: Encyrtidae). Adicionalmente, algunas especies de ambos grupos constituyen nuevos registros de distribución o nuevos hospedantes para México. Las densidades poblacionales de las escamas armadas aumentaron generalmente por huerto y tipo de estructura del árbol, en el periodo de octubre a abril, lo cual dependió de la fenología del cultivo de aguacate; mientras que, los porcentajes de parasitismo y de emergencia de los adultos parasitoides, variaron de acuerdo con el comportamiento de las poblaciones de sus escamas húespedes. La mayor cantidad de parasitoides emergieron de escamas armadas colectadas en ramas (82), seguido de escamas armadas en frutos (59) y escamas armadas en hojas (18).

Palabras Clave: *Hemiberlesia*; *Davidsonaspis*; fluctuación poblacional; parasitismo; Aphelinidae; Signiphoridae

The state of Mexico is the third largest avocado (*Persea americana* Miller; Lauraceae) producer in Mexico. In 2018, it comprised about 5% of the total area (10,458 ha) planted with avocados in Mexico and produced about 5% of the national production, equivalent to 97,806 tons (SIAP 2018). Avocado production in the state of Mexico included 29 municipalities, of which Coatepec Harinas was the largest producer, and together with Villa Guerrero made up nearly 26% of the area planted, with a production volume of 29,694 tons, representing 27.3% of the state total (SIAP 2018). Several avocado cultivars can be found in these municipalities, such as 'Mexican' (native), 'Fuerte,' 'Hass,' and 'Hass-Jimenez,' among others. In recent yr, the Hass cultivar has increased in importance, with more areas planted, and more demand in national and international markets. In these municipalities, the irrational use of certain wide-spectrum insecticides in commercial avocado plantings can affect the natural enemies of armored scale insects, resulting in an increase in pest populations (Lázaro-Castellanos et al. 2012). In recent

[1]Colegio de Postgraduados, Posgrado en Fitosanidad-Entomología y Acarología, km 36.5 Carretera Federal México-Texcoco, Montecillo, Texcoco, Estado de Mexico, C.P. 56230, Mexico; E-mail: lazaro.carlos@colpos.mx (C. L.-C.); hgzzhdz@colpos.mx (H. G.-H.); jnapoles@colpos.mx (J. R.-N.); ladeorar@colpos.mx (L. D. O.-A.); equihuaa@colpos.mx (A. E.-M.)
[2]Universidad Michoacana de San Nicolás Hidalgo, Facultad de Agrobiología "Presidente Juárez," Paseo General Lázaro Cardenas y Berlín s/n, Colonia Viveros, Uruapan, Michoacán, C.P. 60170, Mexico; E-mail: sochoa@umich.mx (S. O.-A.)
*Corresponding author; E-mail: hgzzhdz@colpos.mx

yr, some armored scale species have begun to arise as economically important recurrent pests in several avocado orchards in the state of Mexico. Moreover, the presence of new species may represent a quarantine concern for various countries due to the possible introduction and establishment of these species and the damage they may cause (Evans & Dooley 2013). Armored scales often are efficiently regulated by natural enemies (Rosen 1973), especially parasitoids (Lázaro-Castellanos et al. 2012). In Mexico, except for the work done in Michoacán by Lázaro-Castellanos et al. (2012), there is not enough information on the natural enemies of armored scales on avocado and their potential use in biological control programs. The objectives of the present research were (1) to identify the species of armored scale insects and their parasitoids in commercial avocado plantings of 2 municipalities in the state of Mexico, and (2) to determine the population fluctuation of the most abundant armored scale species, as well as to obtain the percentage of parasitism in each of the armored scale species.

Materials and Methods

Four avocado orchards were selected in the municipalities of Coatepec Harinas and Villa Guerrero. Three orchards were planted with avocado cv. Hass and the other with cv. Hass-Jimenez at Salvador Sánchez Colín Foundation, Coatepec Harinas, Estado de México, Mexico (CICTAMEX, S.C.). The orchards were under conventional agronomic management, and each was geo-referenced (Table 1). In each orchard, 10 trees were selected randomly and marked with a yellow ribbon for monthly samplings. The host substrates evaluated were branches and fruits where the populations were constant during the sampling period. The samplings were conducted from May 2017 to Apr 2018, but on fruits the sampling was done from Jul 2017 to Apr 2018 since from May to Jun 2017, fruits were not present in the orchards.

From each selected tree, 10 branches around 20 cm long with leaves were cut randomly; if fruits were present, 10 were taken also. This material was placed in a brown paper bag (#16) with the respective identification code. Subsequently, the material was transported to the Fruit Pest Lab at Colegio de Postgraduados, Campus Montecillo, Texcoco, Estado de Mexico, Mexico. From 4 branches randomly selected, a 5 cm subsample was taken; if fruits were available, 4 were taken. The selected material was checked with a stereoscopic microscope (American Optical Co., Buffalo, New York, USA) to separate armored scales species. In each armored scales species, the total number of specimens was counted for each developmental stage to record the population fluctuation. The number of specimens with signs of parasitism or emergence orifice on their shell also was registered to estimate the percentage of parasitism. Each armored scale specimen with signs of parasitism was placed in a #0 transparent gelatin capsules to allow for the development and possible emergence of an adult parasitoid. To obtain the parasitoids, the rest of the plant material, not selected for armored scales count also was taken into account. This material was placed in Petri dishes, per armored scales species, with absorbant paper toweling to avoid excess humidity. The Petri dishes and gelatin capsules were kept at room temperature in the laboratory (approximately 20 ± 4 °C and RH 60 ± 10%). This material was checked daily and the emerged parasitoids were collected and sacrificed in 80% alcohol to be mounted later and identified. Live adult female specimens were placed in Eppendorf tubes with 80% alcohol to identify the species of armored scales. Mounting of the armored scales and parasitoids was done on slides with Canada Balsam (Reasol[MR], Delegación Iztapalapa, Ciudad de México, Mexico) using standardized techniques to mount Diaspididae (Kostarab 1963) and parasitic wasps (Noyes 1982). The Ferris (1955) and Evans et al. (2009) keys were used to determine the species of armored scales, whereas for the parasitoid determinations the Myartseva & Evans (2007) keys were used for species of the *Encarsia* genus, Myartseva et al. (2010) for the *Aphytis* genus, Myartseva et al. (2016a) for the *Coccobius* genus, Ramírez-Ahuja et al. (2015) and Wooley & Dal Molin (2017) for the *Signiphora* genus, and Noyes et al. (1997) and reference material for the Encyrtidae family. The identified material was deposited in the Insect Collection of the Colegio de Postgraduados (CEAM), Campus Montecillo, Texcoco, Estado de Mexico, Mexico.

A temporal analysis of armored scales and associated parasitoids on avocado plantings was carried out in the 4 localities. A Kolmogorov-Smirnov test was performed to corroborate the normal distribution of population densities of armored scales and parasitoids. In addition, a Kruskal-Wallis test was used to compare armored scale populations on different tree substrates (branch or fruit). A linear regression was performed to test the relationship between the armored scale population density and their parasitoids. All data were analyzed using the program R vers. 3.4.0. (R CoreTeam 2015).

Climatological data from CONAGUA (Comisión Nacional del Agua: National Commission of Waters) were obtained for locations of Porfirio Díaz (Villa Guerrero), Cochisquila, Ixtlahuaca de Villada, and Coatepec Harinas (Coatepec Harinas) from 1981 to 2010 to analyze the possible effect of temperature and relative humidity on the population density of the armored scales and their natural enemies.

Results

The following species of armored scales (Hemiptera: Diaspididae) were identified: *Hemiberlesia lataniae* (Signoret) [reference numbers CEAM-2017_18-M2Mx1, CEAM-2017_18-M7aMx1-2], *Hemiberlesia cyanophylli* (Signoret) [reference numbers CEAM-2017_18-M2Mx2-4, CEAM-2017_18-M7aMx3-5], *Davidsonaspis aguacatae* (Evans, Watson, & Miller) [reference numbers CEAM-2017_18-M5Mx1-4, CEAM-2017_18-M10Mx1-4], *Hemiberlesia rapax* (Comstock) [reference number CEAM-2017_18-M5Mx5], and *Diaspis* nr. *coccois* (Lichtenstein) [reference number CEAM-2017_18-M10Mx5-8]. Armored scales *H. lataniae* and *H. cyanophylli* were collected from orchards Papalote 1 (Villa Guerrero) and Bordo 2 (Coatepec Harinas); *D. aguacatae* from orchards Cochisquila 1 and La Casita (Coatepec Harinas); *H. rapax* and *D.* nr. *coccois* were collected occasionally from orchards Cochisquila 1 and La Casita, respectively. Armored scales *H. lataniae*, *H. rapax*, *H. cyanophylli*, and *D.* nr. *coccois* were found associated with fruits, branch-

Table 1. Location and geographical coordinates of selected Hass avocado orchards in the municipalities of Coatepec Harinas and Villa Guerrero, State of Mexico, Mexico.

Name of orchard	Geographical coordinates	Altitude (masl)	Municipality, community	Avocado variety
Papalote 1	18.938472°N, 99.722972°W	2,320	Villa Guerrero, Porfirio Díaz	Hass
Cochisquila 1	18.910694°N, 99.752083°W	2,144	Coatepec Harinas, Cochisquila	Hass
La Casita	18.927777°N, 99.813250°W	2,230	Coatepec Harinas, Ixtlahuaca de Villada	Hass
Bordo 2, CICTAMEX	18.917472°N, 99.759305°W	2,244	Coatepec Harinas, Coatepec Harinas	Hass-Jimenez

es, and leaves, whereas *D*. *aguacatae* was associated with fruits and branches. *Diaspis* nr. *coccois* showed a higher population density on leaves, whereas the rest of the species did so on branches and fruits.

The parasitoids obtained from these armored scales on avocado belong to the Aphelinidae, Signiphoridae, and Encyrtidae families (Hymenoptera). From the first family, 8 species were identified: *Encarsia aurantii* (Howard) [reference number CEAM-ECMA2017_18-Ea1-3], *Encarsia citrina* (Craw) [reference number CEAM-ECMA2017_18-Ec1-2], *Encarsia gaonae* (Myartseva & Evans) [reference number CEAM-ECMA2017_18-Eg1-3], *Encarsia lounsburyi* (Berlese & Paoli) [reference number CEAM-ECMA2017_18-Elou1-3], *Aphytis proclia* (Walker) [reference number CEAM-ECMA2017_18-Ap1], *Coccobius averini* (Myartseva) [reference number CEAM-ECMA2017_18-Ca1-4], *Coccobius juliae* (Myartseva) [reference number CEAM-ECMA2017_18-Cj1-2], and *Coccobius mariae* (Myartseva) [reference number CEAM-ECMA2017_18-Cm1]; from Signiphoridae, *Signiphora falcata* (Wooley & Dal Molin) [reference number CEAM-ECMA2017_18-Sfa1-2], *Signiphora fax* (Girault) [reference number CEAM-ECMA2017_18-Sfx1-2], *Signiphora flavella* (Girault) [reference number CEAM-ECMA2017_18-Sfla1-3], and *Signiphora mexicana* (Ashmead) [reference number CEAM-ECMA2017_18-Smx1]; from Encyrtidae only *Plagiomerus diaspidis* (Crawford) was identified [reference numbers CEAM-ECMA2017_18-Pd1-2]. Information on geographical distribution and hosts of each parasitoid species also is included (Table 2).

The population fluctuation was studied only in the case of armored scales *D*. *aguacatae*, *H*. *cyanophylli*, and *H*. *lataniae*, because they were the most abundant scale species. In general, the population density of these armored scales decreased during the rainy period in the region from Jul to Sep 2017, except in the Papalote 1 orchard. In La Casita, Cochisquilla 1, and Papalote 1, armored scale population densities increased from Oct 2017 to Jan 2018, although in orchards Bordo 2 and Papalote 1, the highest scale density was observed in Feb and Mar 2018, respectively (Fig. 1). The Kolmogorov-Smirnov test showed that the population densities of the armored scales (D = 0.39098; p < 2.961e-09) and parasitoids (D = 0.75758; p < 2.2e-16) showed a normal distribution. Levels of parasitism increased in Oct 2017, especially in orchards Papalote 1 and La Casita, whereas in orchard Bordo 2, parasitism increased in Dec 2017 (Fig. 2). A positive correlation between the population density of armored scales and the percentage of parasitism was observed (R-squared: 0.4654; df = 97; p = 0.005874; confidence: 99%) (Fig. 3).

Table 2. Armored scales, distribution, and abundance of parasitoid species in Hass avocado orchards of the State of Mexico, Mexico.

Scale species	Orchard and municipality	Parasitoid species (# specimens: # per sex)
Hemiberlesia cyanophylli	Papalote 1, Villa Guerrero	*Encarsia aurantii* (26: 23♀, 3♂)
		Encarsia citrina (7♀)
		Encarsia gaonae (19: 13♀, 6♂)
		Coccobius averini (4: 2♀, 2♂)
		Coccobius juliae (4♀)
		Signiphora falcata (2: 1♀, 1♂)
		Plagiomerus diaspidis (1♂)
	Bordo 2, Coatepec Harinas	*Coccobius juliae* (1♂)
		Coccobius mariae (1♀)
		Signiphora mexicana (1♀)
		Plagiomerus diaspidis (1♂)
Davidsonaspis aguacatae	Cochisquila 1, Coatepec Harinas	*Encarsia aurantii* (1♀)
		Coccobius averini (2: 1♀, 1♂)
		Coccobius juliae (2♀)
	La Casita, Coatepec Harinas	*Encarsia aurantii* (1♀)
		Encarsia citrina (6♀)
		Encarsia lounsburyi (27)
		Aphytis proclia (2♀)
		Coccobius averini (3♂)
		Coccobius juliae (2♂)
		Plagiomerus diaspidis (1♂)
Diaspis nr. *coccois*	La Casita, Coatepec Harinas	*Encarsia lounsburyi* (4♀)
		Coccobius juliae (1♂)
		Coccobius mariae (1♀)
Hemiberlesia lataniae	Papalote 1, Villa Guerrero	*Encarsia aurantii* (5: 4♀, 1♂)
		Encarsia citrina (2♀)
		Encarsia gaonae (11: 9♀, 2♂)
		Encarsia lounsburyi (1♀)
		Coccobius juliae (2: 1♀, 1♂)
		Signiphora falcata (1♀)
		Signiphora fax (2♀)
	Bordo 2, Coatepec Harinas	*Coccobius averini* (4: 2♀, 2♂)
		Coccobius juliae (2: 1♀, 1♂)
		Coccobius mariae (1♀)
		Signiphora fax (1♂)
		Signiphora flavella (3♀)
		Plagiomerus diaspidis (2♂)
		Encyrtidae sp. 1 (1♀)
		Encyrtidae sp. 2 (1♀)
Hemiberlesia rapax	Cochisquila 1, Coatepec Harinas	*Plagiomerus diaspidis* (1♀)

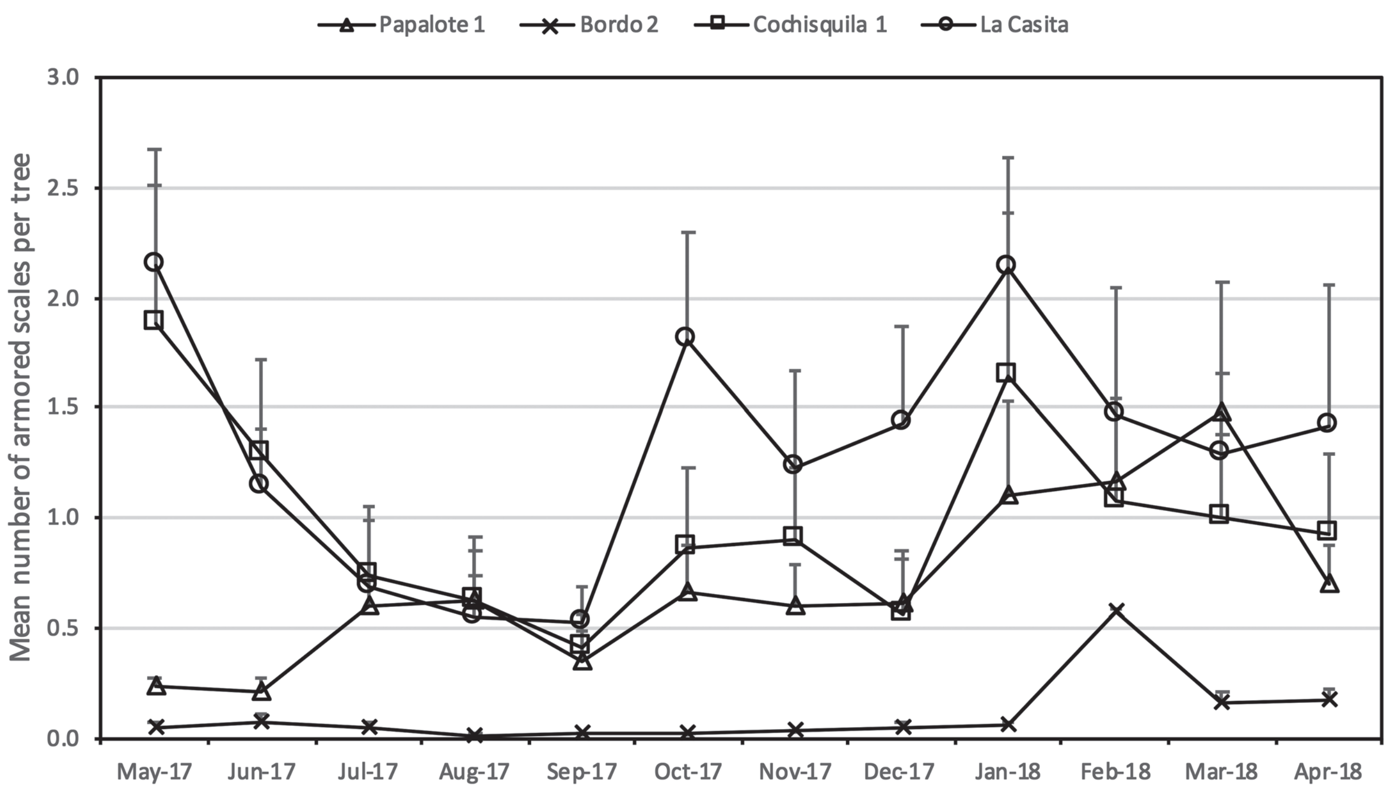

Fig. 1. Mean armored scales in 4 Hass avocado orchards in Coatepec Harinas and Villa Guerrero, Estado de Mexico, Mexico, from May 2017 to Apr 2018.

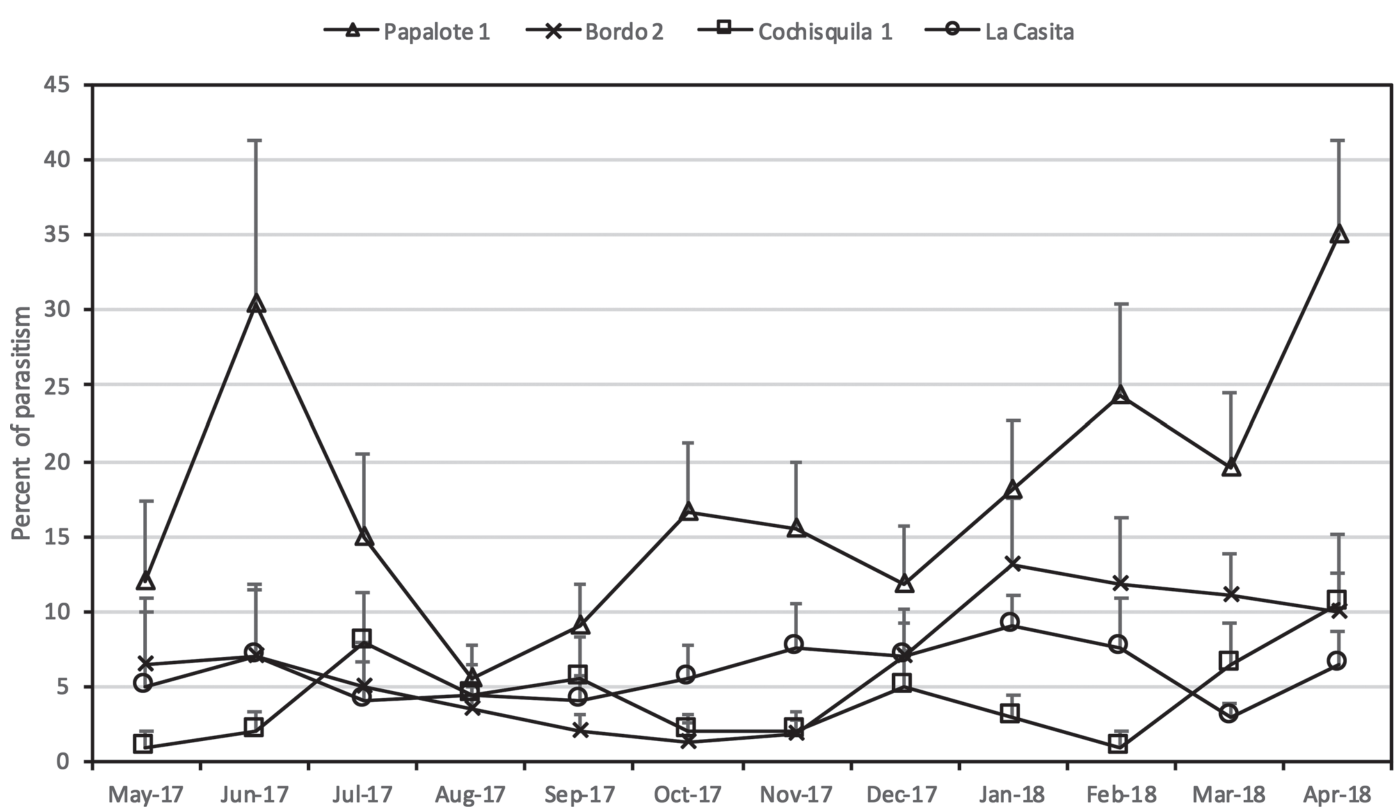

Fig. 2. Percentage of parasitism in armored scale in 4 Hass avocado orchards in Coatepec Harinas and Villa Guerrero, Estado de Mexico, Mexico, from May 2017 to Apr 2018.

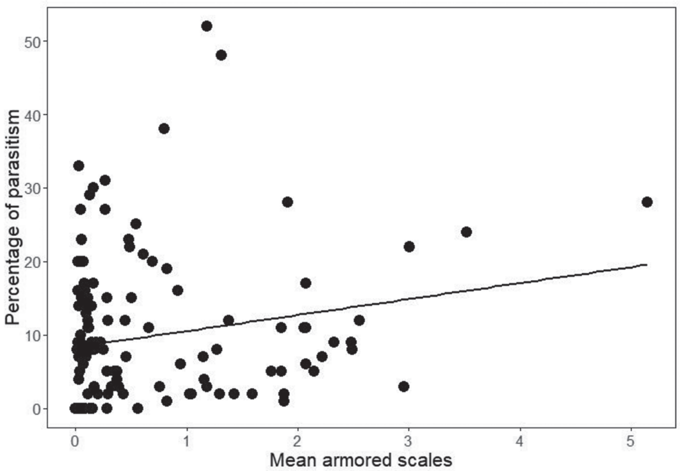

Fig. 3. Regression between percentage of parasitism and mean armored scales on Hass avocado orchards in Coatepec Harinas and Villa Guerrero, Estado de Mexico, Mexico.

The Kruskal-Wallis test (χ^2 = 17.161; df = 2; p = 0.0001878) indicated differences in the distribution of 2 species of armored scales; *D. aguacatae* was more abundant on branches whereas *H. cyanophylli* was more abundant on fruits (Fig. 4).

In orchard Papalote 1 (Villa Guerrero), *H. cyanophylli* was present on branches with very low population densities from 0.004 to 0.180 armored scales per branch. The peaks of population densities were observed in the months of May, Aug, Oct, and Dec 2017, and Apr 2018 (Fig. 5a), but the most constant populations were observed in the period from May to Aug 2017. Regarding parasitism, the highest percentages were reached in Jun 2017, and from Mar to Apr 2018, with 30, 23, and 29%, respectively (Fig. 5a). In the remaining mo, percentage of parasitism oscillated between 8 and 16%.

In the case of *H. lataniae*, the densities also were lower, with a mean of 0.15 to 0.80 armored scales per branch. The highest peaks were observed in Oct and Nov 2017 with densities near 0.5 armored scales per branch, and in Jan and Apr 2018, with densities of 0.6 and 0.8 armored scales per branch, respectively (Fig. 5b). Parasitism, in this case, was greater in Jun 2017 and Apr 2018, with 31 and 38%, respectively. In the remaining mo, the percentages ranged between 8 and 23% (Fig. 5b). On fruits, *H. cyanophylli* showed mean population densities from 1.15 to 5.14 armored scales per fruit, with peaks in Jan and Mar 2018 with densities from 3 to 5 armored scales per fruit (Fig. 5c). The parasitism of *H. cyanophylli* reached its highest levels in Oct 2017 and Apr 2018 with levels of 28 and 48%, respectively (Fig. 5c), whereas in the remaining mo it ranged between 4 and 22%. With regard to *H. lataniae*, the population densities were even lower, where they oscillated between 0.004 and 1.17 armored scales per fruit, and in some mo, they were almost imperceptible (Fig. 5d); however, the highest

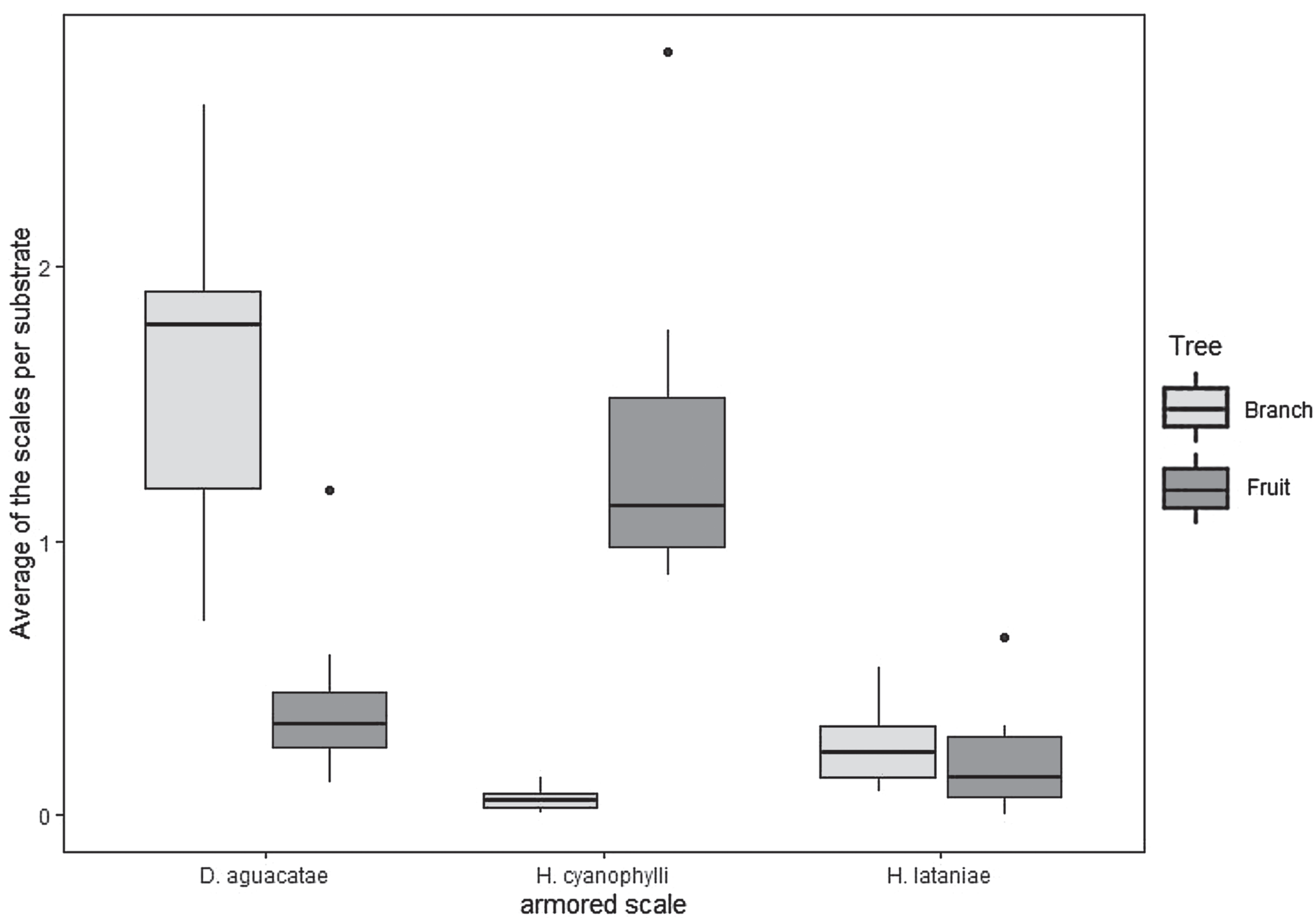

Fig. 4. Mean of armored scale on branches and fruits in Hass avocado orchards in Estado de Mexico, Mexico (Coatepec Harinas and Villa Guerrero).

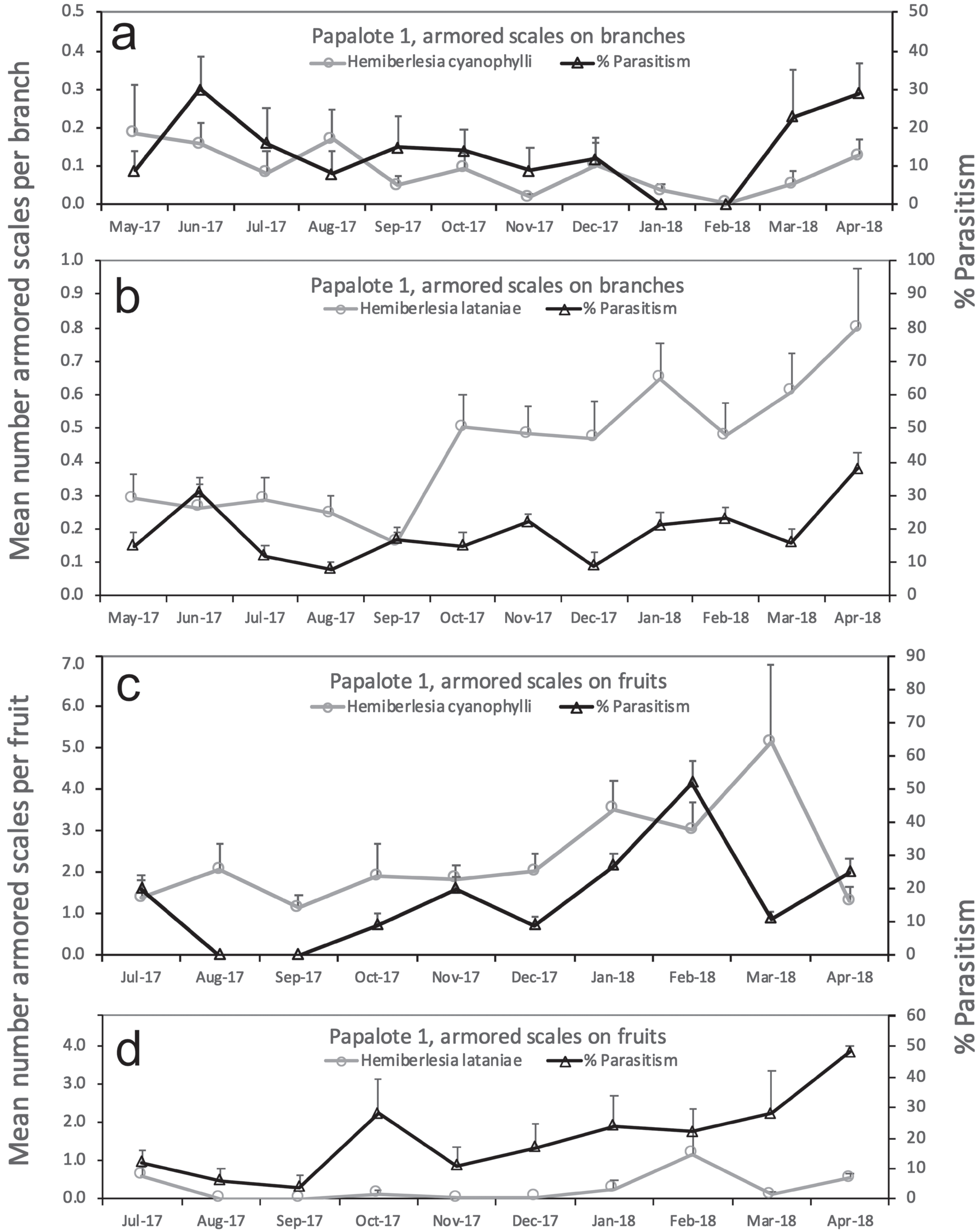

Fig. 5. Mean *Hemiberlesia cyanophylli* and *Hemiberlesia lataniae* armored scales and percentage of parasitism on branches (a, b) and fruits (c, d) on Hass avocado in the Papalote 1 orchard (Villa Guerrero) from May 2017 to Apr 2018.

peaks were observed in Jul 2017 and Feb 2018. Parasitism on fruits reached its highest peak in Feb 2018 with 52% (Fig. 5d).

In orchard Cochisquila 1 (Coatepec Harinas), *D. aguacatae* was present on branches at mean population densities between 0.6 and 2.9 armored scales per branch, reaching their highest peaks in May 2017 and Jan 2018 (Fig. 6a). Parasitism was greater in Jul and Sep 2017 with levels of 16 and 11%, respectively. The remaining mo had percentage parasitism between 1 and 5% (Fig. 6a). On fruits, *D. aguacatae* registered mean population densities even lower, between 0.06 and 0.82 armored scales per fruit, being the highest in Jul 2017 and Apr 2018 (Fig. 6c) with densities over 0.6 armored scales per fruit. Parasitism reached its highest peak in Aug and Dec 2017, and Apr 2018 with 8, 8, and 19%, respectively; in the remaining mo, it oscillated between 0 and 6% (Fig. 6c).

In orchard La Casita (Coatepec Harinas) on branches, *D. aguacatae* showed mean population densities ranging from 0.75 and 2.55 armored scales per branch. The highest population density peaks were in May, Oct, and Dec 2017, and Feb and Apr 2018, with around 2.5 mean armored scales per branch (Fig. 6b). Parasitism reached its highest levels in Nov 2017 and Feb 2018 with 11 and 12%, respectively, and in the remaining mo, it was from 3 to 9%. On fruits, *D. aguacatae* showed mean densities ranging from 0.08 to 2.05 armored scales per fruit. The highest density was reached in Jan 2018 with over 2.0 armored scales per fruit (Fig. 6d). Parasitism was highest also in the mo of Jan 2018 with 11% whereas in the remaining mo it was between 0 and 5% (Fig. 6d).

In orchard Bordo 2 (Coatepec Harinas) on branches, *H. cyanophylli* showed very low population densities between 0.008 and 0.09 mean armored scales per branch. The highest density was registered in May 2017 and Mar 2018 (Fig. 7a). Parasitism was registered only in 4 mo during May 2017 and Apr 2018 with the level of 13 and 10%, respectively, and in the remaining mo it was between 4 and 9% (Fig. 7a). In the case of *H. lataniae*, the population densities ranged between 0.008 and 0.14 mean armored scales per branch with the highest peaks in Jun 2017 and Jan and Apr 2018 (Fig. 7b). Parasitism showed its highest levels in Jul 2017 and Feb 2018 with 20 and 27%, respectively. In the remaining months, the levels ranged from 0 to 16% (Fig. 7b). On fruits, *H. cyanophylli* showed mean population densities ranging between 0.008 and 0.45 armored scales per fruit, reaching its highest density in the mo of Mar and Apr 2018 (Fig. 7c). Parasitism was registered in the period from Dec 2017 to Apr 2018 reaching its highest peak in Jan 2018 at 33%. In the remaining mo, parasitism ranged between 7 and 20% (Fig. 7c). *Hemiberlesia lataniae* showed population densities between 0.004 and 0.12 mean armored scales per fruit. The highest densities were in the mo from Feb to Apr 2018 (Fig. 7d), whereas no presence of the species was detected in Aug 2017. Parasitism in this species was present only in the mo of Jan, Mar, and Apr 2018 with 17, 15, and 11%, respectively (Fig. 7d).

From the armored scales material collected and kept in the laboratory, 159 parasitoid specimens emerged; 88 came from Papalote 1 orchard, 6 from Cochisquila 1, 48 from La Casita, and 17 from Bordo 2 (Table 2). The numbers of parasitoids obtained per avocado tree substrates were 18 on leaves, 59 on fruits, and 82 on branches. The most abundant parasitoid species were *E. aurantii* with 33 specimens associated with armored scales *H. cyanophylli*, *D. aguacatae*, and *H. lataniae*; *E. lounsburyi* with 32 specimens associated with armored scales *D. aguacatae*, *D.* nr. *coccois*, and *H. lataniae*; *E. gaonae* with 27 specimens associated with armored scales *H. cyanophylli* and *H. lataniae*; *E. citrina* with 15 specimens associated with armored scales *H. cyanophylli*, *D. aguacatae*, and *H. lataniae*; *C. juliae* with 14 specimens associated with armored scales *H. cyanophylli*, *D. aguacatae*, *D.* nr. *coccois*, and *H. lataniae*; and the parasitoid *C. averini* with 13 specimens associated with armored scales *H. cyanophylli*, *D. aguacatae*, and *H. lataniae*. The rest of the parasitoid species were obtained in numbers from 1 to 6 specimens. The Encyrtidae *Plagiomerus diaspidis* was the only species obtained from the 5 armored scale species, although with few specimens (6) (Table 2). The mo in which the greatest number of parasitoids emerged were from Oct 2017 to Mar 2018, with a decrease in Apr and increasing in May 2018 (Table 3). The development stages from which the parasitoid species emerged were, from greatest to lowest, adult female, nymph 3, males, and nymph 2; on the last one, 3 species of *Encarsia* were obtained (Table 4).

Discussion

From the 5 species of armored scales identified in the present study, 4 have been reported previously associated with avocado orchards in Mexico. González and Atkinson (1984) registered *H. lataniae* and *H. rapax* in some Rosaceae species and on avocado in Texcoco and Villa del Carbón, in Estado de Mexico. Also, Lázaro-Castellanos et al. (2012) reported *H. lataniae*, *H. rapax*, and *D. aguacatae* present in Hass avocado in the municipalities of Ario de Rosales, Nuevo San Juan Parangaricutiro, Los Reyes, Periban, Salvador Escalante, Tacámbaro, Tingambato, and Ziracuaretiro, Michoacán. González and Atkinson (1984) registered *Diaspis* nr. *coccois* in the central region of Mexico, although without specifying its geographical distribution. This latter species also has been collected from Hass avocado and cv. Mexicano (native) in several municipalities in Michoacán (González-Hernández, Fitosanidad-Entomología y Acarología, Colegio de Postgraduados, personal communication). Meanwhile, Morse et al. (2009) mention that *D.* nr. *coccois* could be misidentified, because it has been detected only in palm trees. This scale was determined as *D.* nr. *coccois* based on the middle lobules (L1) forming a median notch in the pygidium, lack of ear-like lateral prothoracic protuberances, and lack of submedial dorsal micropores in segments VI and VII of the pygidium. According to the descriptions by Ferris (1954), McKenzie (1956), and Boratynski (1968), these morphological characters are very similar to *D. coccois*. Also, it is possible that it could be a new species, and given its morphological likeness to the coconut armored scales, it has been named as *Diaspis* nr. *coccois* until it can be correctly determined. With regard to *H. cyanophylli*, the second author of this paper has collected the species from Hass avocado in orchards in the municipalities of Tancítaro, Zitácuaro, and Uruapan, Michoacán (González-Hernández, Fitosanidad-Entomología y Acarología, Colegio de Postgradudados, personal communication). In the present study, *D. aguacate* represents the first record of the species in Estado de Mexico, as well as a new record of national distribution, because it had previously been reported only in Hass avocado in Michoacán, where it was considered endemic (Evans et al. 2009; Lázaro-Castellanos et al. 2012).

The 4 *Encarsia* species determined in the present research have been reported in Mexico as parasitoids of several species of armored scales (Myartseva et al. 2016b). Myartseva and Evans (2007) indicate that in Mexico, *E. aurantii* has been detected on *Chrysomphalus aonidum* (L.) and *Aonidiella aurantii* Maskell (both Hemiptera: Diaspididae) in the states of Baja California Sur, Tamaulipas, and Jalisco. This species was introduced successfully to Mexico to control *Ch. aonidum* in 1949 to 1950. Moreover, *Encarsia* species have been reported around the world attacking other species of armored scales of *Aonidiella*, *Aspidiotus*, *Chrysomphalus*, *Diaspidiotus*, *Hemiberlesia*, *Insulaspis*, *Lepidosaphes*, *Melanaspis*, *Parlatoria*, *Pinnaspis*, *Pseudalacaspis*, *Parlatoria*, and *Quadraspidiotus* (now *Diaspidiotus*) (all Hemiptera: Diaspididae) among others (Myartseva & Evans 2007). *Encarsia citrina* has been reported attacking *D. aguacatae*, *H. lataniae*, and *H. rapax* in Hass

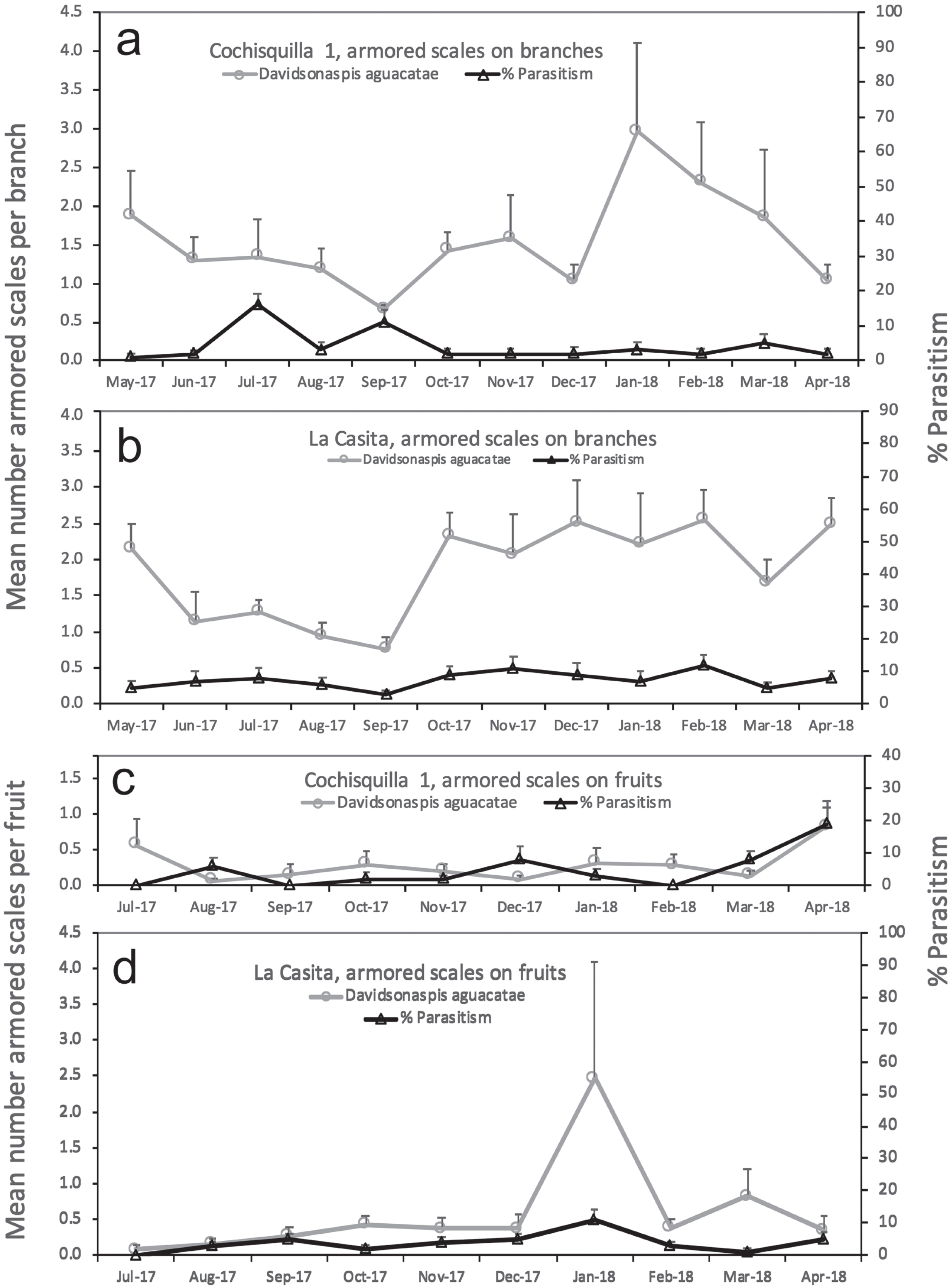

Fig. 6. Mean *Davidsonaspis aguacatae* armored scale on branches and fruits of Hass avocado and percentage of parasitism in Cochisquila 1 (a, c), and La Casita (b, d) orchards (Coatepec Harinas) from Jul 2017 to Apr 2018.

Table 3. Months of the emergence of the most abundant parasitoids associated to armored scales in Hass avocados in the State of Mexico, Mexico, from Jun 2017 to May 2018.

Date	*E. aurantii*	*E. citrina*	*E. gaonae*	*E. lounsburyi*	*C. averini*	*C. juliae*	*P. diaspidis*
Jun 17	2	0	2	0	0	0	0
Jul 17	2	0	0	0	3	1	1
Aug 17	0	0	0	0	0	0	0
Sep 17	7	0	0	0	2	0	0
Oct 17	1	2	0	7	0	1	0
Nov 17	3	2	4	14	2	1	0
Dec 17	3	4	3	3	0	3	0
Jan 18	6	4	3	5	0	2	2
Feb 18	1	3	3	3	0	0	1
Mar 18	3	0	9	0	2	2	1
Apr 18	1	0	1	0	2	0	1
May 18	4	0	5	0	2	4	0
Total	33	15	30	32	13	14	6

avocado in Michoacán, Mexico, and was proposed as the parasitoid species with the greatest potential as a biological control agent of these armored scales in Hass avocado orchards in Michoacán, Mexico (Lázaro-Castellanos et al. 2012). *Encarsia gaonae* has been obtained from *Pinnaspis strachani* (Cooley) (Hemiptera: Diaspididae) associated with *Amyris madrensis* Watson (Rutaceae) in Ciudad Victoria, Tamaulipas, Mexico (Myartseva & Evans 2007). *Encarsia lounsburyi* is a cosmopolitan species very similar to *E*. *citrina*, although with some morphological differences that allow one to separate them (Myartseva & González-Hernández 2007). *Encarsia lounsburyi* has been found as a parasite of *D*. *aguacatae* on Hass avocado fruits in shipments from Michoacán, Mexico, destined to Florida, USA (Stocks & Evans 2017). In the present study, all 4 parasitoid species present new geographical distribution records in Mexico. Furthermore, *E*. *aurantii* presents 3 new host records in Mexico: *H*. *cyanophylli*, *D*. *aguacatae*, and *H*. *lataniae*. Meanwhile, *E*. *gaonae* has 2 new host records: *H*. *cyanophylli* and *H*. *lataniae*. In the case of *E*. *lounsburyi*, it has 2 new host records: *D*. nr. *coccois* and *H*. *lataniae*.

Aphytis proclia has a Holarctic origin and is considered almost cosmopolitan given its wide distribution around the world. In Mexico, it has been obtained from *Ch*. *aonidum* and *Ch*. *dyctiospermi* on citrus fruits in the state of Veracruz, Mexico. Around the world, it has been registered as a parasite of over 60 species of Diaspididae (Myartseva et al. 2010). The present record of *D*. *aguacatae* represents a new geographical distribution for the country and as a new host.

The species of *Coccobius* generally are parasites of armored scales in several regions around the world (Prinsloo 1995; Evans & Pedata 1997; Myartseva 2015); some even have been introduced to different countries to control economically important armored scales (Wang et al. 2014; Myartseva 2015; Myartseva et al. 2016a). They are primary endo-parasitoids and the males are ecto- or endohyper- parasitoids of females in the same species of other parasitoids (Prinsloo 1995). Seven species are reported in Mexico, such as *C. averini*, *C*. *juliae*, and *C*. *mariae*, detected at Las Barracas, Baja California Sur, Mexico (Myartseva 2015; Myartseva et al. 2016a). In the present study, a new geographical distribution is reported for the 3 parasitoid species, as well as new host registries for *C*. *averini*, being a parasite of *H*. *cyanophylli*, *D*. *aguacatae*, and *H*. *lataniae*. *Coccobius juliae* is reported being a parasite of armored scales *H*. *cyanophylli*, *D*. *aguacatae*, *D.* nr. *coccois*, and *H*. *lataniae*, and *C. mariae* of armored scales *H*. *cyanophylli*, *D*. nr. *coccois*, and *H*. *lataniae* (Myartseva 2015; Myartseva et al. 2016a).

The 4 species of *Signiphora* registered in this paper have been reported as hyperparasitoids of armored scales in Mexico and other countries. Other species in this genus are parasitiods or hyperpara-

Table 4. Parasitoid emergence by the state of development of armored scales in Hass avocados in the State of Mexico, Mexico, from Jun 2017 to May 2018.

Species	N2*	N3*	Adult females	Males	Total
Encarsia aurantii	1	14	10	8	33
Encarsia citrina	2	3	5	5	15
Encarsia gaonae	0	9	16	5	30
Encarsia lounsburyi	10	5	4	13	32
Aphytis proclia	0	1	1	0	2
Coccobius averini	0	3	9	1	13
Coccobius juliae	0	3	11	0	14
Coccobius marie	0	0	2	0	2
Signiphora falcata	0	0	1	2	3
Signiphora fax	0	1	0	2	3
Signiphora flavella	0	1	2	0	3
Signiphora mexicana	0	0	1	0	1
Plagiomerus diaspidis	0	0	5	1	6
Encyrtidae sp. 1	0	0	1	0	1
Encyrtidae sp. 2	0	0	1	0	1
Total	13	41	70	38	159

*N2 = Nymph second instar; N3 = Nymph third instar.

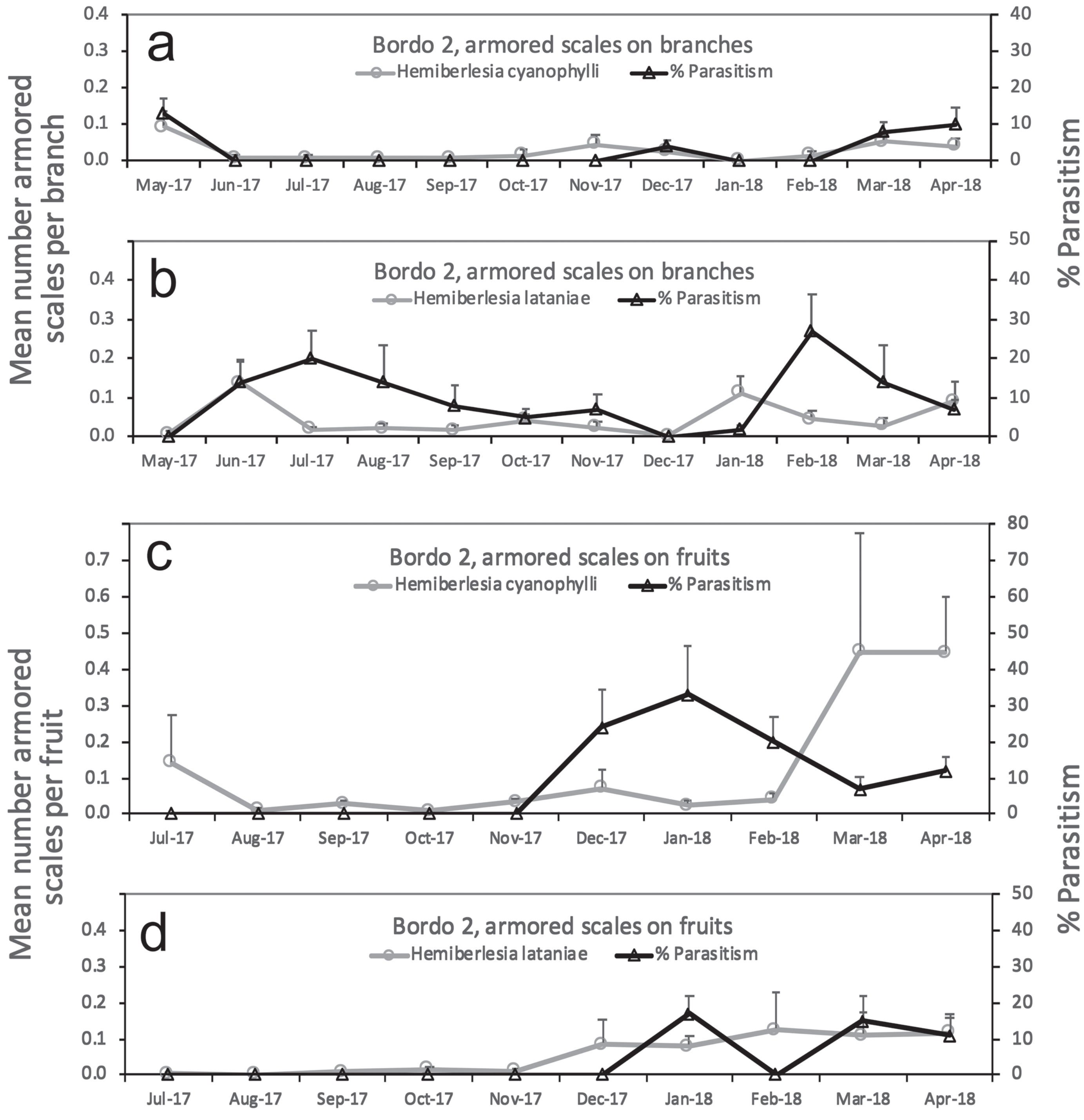

Fig. 7. Mean *Hemiberlesia cyanophylli* and *Hemiberlesia lataniae* armored scales and percentage of parasitism on branches (a, b) and fruits (c, d) on Hass avocado in the Bordo 2 orchard (Villa Guerrero) from May 2017 to Apr 2018.

sitoids of armored scales and mealybugs (Ramírez-Ahuja et al. 2015; Woolley & Dal Molin 2017). In Mexico, *S. falcata* has been obtained from some species of Diaspididae in the states of Michoacán, Guanajuato, and Nuevo León (in the municipalities of Monterrey and Linares). In Nuevo Leon, *S. falcata* was reported parasitizing the armored scale *Mycetaspis personata* (Comstock) (Hemiptera: Diaspididae) on avocado. The male of this species is considered to be a hyperparasitoid. Also, in Brazil, it has been obtained from armored scale *Pseudaonidia trilobitiformis* (Green) (Hemiptera: Diaspididae) (Woolley & Dal Molin 2017). *Signiphora fax* Girault (Hymenoptera: Signiphoridae) has been recorded as a parasitoid of *Ao. aurantii*, *H. lataniae*, *L. beckii*, *Aonidomytilus espinosai* (Porter), *Aspidiotus* spp., *Chrysomphalus* spp., *Chionaspi* ssp. (all Hemiptera: Diaspididae), and the Aleyrodidae *Aleurothrixus floccosus* (Maskell) (Hemiptera: Aleyrodidae). It is believed that *S. fax* also is a hyperparasitoid of *Aphytis lepidosaphes* (Compere) (Hymenoptera: Aphelinidae). In Mexico, it has been registered, but with no information on the host or its distribution (Woolley & Dal Molin 2017). *Signiphora flavella* commonly is a parasite of armored scales and has a cosmopolitan distribution (Woolley & Dal Molin 2017). It is a primary parasitoid of *H*. *lataniae* and *H*. *rapax* in California, USA. Meanwhile, in Mexico it has been collected from armored scales in citrus fruits in Xoxocotlan, Oaxaca; in *Aspidiotus* sp. feeding on *Myrtus* sp. (Myrtaceae) in Orizaba, Veracruz, and on avocado in Uruapan, Michoacán (Ramírez-Ahuja et al. 2015). Around the world, *S. flavella* also has been obtained from species of *Aonidiella*, *Aspidiotus*, *Aulacaspis*, *Lepidosaphes*, *Hemiberlesia*, *Parlatoria*, and *Diaspidiotus* (Woolley & Dal Molin 2017). *Signiphora mexicana* has been registered for Mexico in the state of San Luís Potosí and Xochipala, Guerrero, and is a parasitoid of the *A*. *nerii*, and a soft scale (without specifying the species) on *Opuntia* (Cactaceae). In other countries, it attacks also species of *Chrysomphalus*, the soft scales *Pulvinaria* and *Coccus* (Hemiptera: Coccidae) (Ramírez-Ahuja et al. 2015). In the present study, all 4 Signiphoridae species represent new distribution in the state of Mexico, as well as the new host in Mexico, because S. *falcata* was detected as a parasitoid of *H*. *cyanophylli* and *H*. *lataniae*. Meanwhile, *S*. *fax* is a new record on *H*. *lataniae*, as well as *S*. *flavella* on *H*. *lataniae*, and *S*. *mexicana* on *H*. *cyanophylli*.

The encyrtid *Plagiomerus diaspidis* already has been reported associated with armored scales on avocado in Michoacán, Mexico (Lázaro-Castellanos et al. 2012). The species of this family develop as endo-parasitoids of armored scales. *Plagiomerus diaspidis* is a new distribution record for Estado de México, Mexico, as well as 3 new host registries, because it is a parasitoid of *H*. *cyanophylli*, *D*. *aguacatae*, and *H*. *rapax*.

Regarding the population fluctuation of armored scales, *D. aguacatae* showed greater population growth on avocado branches during the period from Oct 2017 to Jun 2018, whereas on fruits it was from Oct 2017 to Apr 2018. In the latter case, the difference is because, after Apr there are no more large fruits due to harvest. Additionally, *D. aguacate* showed a higher mean population density on branches than on fruits (Fig. 5). The *D. aguacate* populations increased during this period (Oct–Jun), when the mean temperatures oscillated between 13 and 17.8 °C, in Cochisquila and Ixtlahuaca de Villada (Coatepec Harinas) (CONAGUA 2018), and with mo when rainfall was the lowest, as in Oct when it fell from 98.2 to 68.3 mm per mo, and in Dec it fell from 12.0 to 7.5 mm. On the other hand, in mo with greater rainfall, the armored scales populations decreased perceptively from Jun to Sep (CONAGUA 2018). According to McClure (1990), some factors like temperature or humidity may affect the survival and spread of armored scales after the establishment of the crawler.

In some cases, such as in the orchard Papalote 1, *H. cyanophylli* showed its highest densities on fruits from Oct 2017 to Apr 2018 (Fig. 5a, c) when the mean temperatures oscillated between 12 and 17.5 °C in the localities of Porfirio Díaz (Villa Guerrero) and Coatepec Harinas (CONAGUA 2018). Since Oct, rainfall had decreased but increased considerably in Jun, thus the population fluctuation of *H. cyanophylli* was similar to that of *D*. *aguacatae*, with a decline in mo with greater rainfall. *Hemiberlesia cyanophylli* is found occasionally in greater numbers on branches; its populations increased from Mar to Aug 2017, mo when the mean temperatures were higher, between 15.2 and 17.8 °C. The greatest rainfall of the yr was registered during the same period (Jun to Aug) (CONAGUA 2018).

Hemiberlesia lataniae was present in the same orchards as *H*. *cyanophylli*, and their population on branches and fruits had similar densities (Fig. 5). On branches, occasionally it was the species with the highest population density, as in the case of the Papalote 1 orchard. In general, the *H. lataniae* population increased from Oct 2017 to Apr 2018, making its behavior similar to those of other armored scale species. On the other hand, it was occasionally the species with the lowest population density on fruits, as in the orchard Papalote 1 (Fig. 5d). This armored scale population generally increased from Jan to Apr, with mean temperatures from 12.1 to 17.5 °C and monthly rainfall of 10.6 to 30.7 mm (CONAGUA 2018). Both species, *H*. *lataniae* and *H*. *cyanophylli*, shared distribution on the tree structures, although they showed differences in the behavior of their population densities per tree substrates. McClure (1990) mentions that when 2 or more Diaspididae species share the same host, they can occupy different parts of the plant to avoid interspecific competition, besides temporal distribution where a species increases its populations in the warmer or colder mo.

The species of *Encarsia* were the most abundant armored scale parasitoids, followed by the *Coccobius* species. In this regard, Heraty et al. (2008) mentioned that species of *Encarsia* are some of the most exploited groups for the control of armored scales in agricultural environments besides being the largest and most diverse genus of Aphelinidae, with species specialized in attacking armored scales. Moreover, in many of the species of *Encarsia*, the males act as hyperparasitoids of their own females or others in the same genus, although this hyperparasitism characteristic also is shared by many species of *Coccobius* (Prinsloo 1995) and *Signiphora* (Woolley & Dal Molin 2017), as well as some Encyrtidae species (Noyes et al. 1997), which are parasitoids that may regulate armored scales populations. *Encarsia aurantii*, *E*. *citrina*, and *E*. *lounsburyi* are documented to have been introduced into Mexico in classical biological control programs to manage armored scales (Myartseva & Evans 2008). In the present study, the first 2 showed greater distribution and host diversity, whereas *E*. *lounsburyi* showed a preference for *D*. *aguacatae* (Table 2). On the other hand, *E*. *citrina* showed a lower density on the armored scales with the greatest abundance in the orchards. This agrees partially with Lázaro-Castellanos et al. (2012) for Michoacán, where it was detected as a parasitoid associated with *H*. *lataniae*, *D*. *aguacatae*, and *H*. *rapax*, present in Hass avocado orchards, and it was also the parasitoid species with the greatest abundance and distribution.

In the present study, *E. aurantii* was the most abundant and most distributed species. In Egypt, *E. aurantii* is considered one of the main regulatory agents of this group of insects (Abd-Rabou et al. 2014). *Encarsia gaonae* was reported by Myartseva and Evans (2007) as having a limited distribution and host range in Mexico. *Encarsia gaonae* is reported for the first time being associated with 2 species of armored scales on avocado.

The species of *Coccobius* with the greatest density and distribution in the orchard Bordo 2 in Coatepec Harinas were *C*. *averini* and *C*. *juliae*, which represent new distribution and host records for these species, although Myartseva et al. (2016a) reported both of these species from Baja California Sur, Mexico, but without host records. *Coccobius* is a medium-sized genus in the number of species of Aphelinidae, most of which are reported as specialized parasitoids in scale insects (Evans & Pedata 1997). Moreover, they are highly appreciated in biological control programs to manage armored scales in Asia, especially in China, where *Coccobius azumai* (Tachikawa) (Hymenoptera: Aphelinidae) was successfully introduced to control *Hemiberlesia pitysophila* (Takagi) (Hemiptera: Diaspididae), an important species in pine trees (Wang et al. 2014).

All parasitoids obtained were principally armored scale adult females and third instar nymphs (N3), although there were some species that attacked second instar nymphs (N2). *Encarsia citrina* attack females from N2 individuals to adults and males from N2 individuals to pupa (Lázaro-Castellanos et al. 2012), and it has been reported that according to the temperature, it can show a certain preference for younger development stages (Bayoumy et al. 2013). Although *E. lounsburyi* is a parasite of all developmental stages, it was commonly detected in N2 individuals; moreover, this species is morphologically very close to *E*. *citrina* (Myartseva & González-Hernández 2007), and they are found parasitizing the same group of species (Myartseva & Evans 2007); therefore, it is possible that they share certain attack habits, as happens in closely related species (Heraty et al. 2008). In the present study, both species also were present in the same period of the yr (Table 3), although with different distribution and abundance (Table 2). *Encarsia aurantii* prefers the more developed instars of the host (adults and third instar); on only 1 occasion was it obtained from an N2.

The population density of the most frequently detected parasitoids (Fig. 2) in the Estado de México showed a clear dependence on the density of their host (Fig. 1), which is associated with a density-dependence relationship, mainly the *Encarsia* species, during the months of Oct 2017 to Mar 2018 (Table 3) as the period when the density of armored scales increased. This is similar to the report by Lázaro-Castellanos et al. (2012) in Michoacán, where they observed that in the mo when the populations of armored scales increased, so did the percentage of parasitism.

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References Cited

Abd-Rabou S, Ahmed N, Evans GA. 2014. *Encarsia* Forester (Hymenoptera: Aphelinidae) effective parasitoids of armored scale insects (Hemiptera: Diaspididae) in Egypt. Acta Zoologica Bulgarica, Supplement 6: 7–12.

Bayoumy MH, Abdel-Kareim AI, Abdel-Salam AH. 2013. Biological assessment of *Encarsia citrina* (Hymenoptera: Aphelinidae) a parasitoid of euonymus scale *Unaspis euonymi* (Hemiptera: Diaspididae). Acta Phytopathologica et Entomologica Hungarica 48: 269–282.

Boratynski K. 1968. A note on some species of the genus *Diaspis* Costa, 1828, (Hemiptera, Coccoidea) in the Collections of the Naturhistorisches Museum in Vienna; with the description of a new species. Annalen Naturhistorischen Museums in Wien 72: 33–43.

CONAGUA – Comisión Nacional del Agua. 2018. Información climatológica. Servicio Meteorológico Nacional. http://smn.conagua.gob.mx/es/informacion-climatologica-ver-estado?estado=mex (last accessed 2 Mar 2021).

Evans GA, Pedata PA. 1997. Parasitoids of *Comstockiella sabalis* (Homoptera: Diaspididae) in Florida and description of a new species of the genus *Coccobius* (Hymenoptera: Aphelinidae). Florida Entomologist 80: 328–334.

Evans GA, Dooley JW. 2013. Potential invasive species of scale insects for the USA and Caribbean Basin. pp. 320–341 *In* Peña J [ed.], Potential Invasive Pests of Agricultural Crops. CAB International, Wallingford, United Kingdom.

Evans GA, Watson GW, Miller DR. 2009. A new species of armored scale (Hemiptera: Coccoidea: Diaspididae) found on avocado fruit from Mexico and a key to the species of armored scales found on avocado worldwide. Zootaxa 1991: 57–68.

Ferris GF. 1954. Atlas of the scale insects of North America. Series I. The Diaspididae (Part I). Second Printing. Stanford University Press, Stanford, California, USA.

Ferris GF. 1955. Atlas of the scale insects of North America. Series IV. The Diaspididae (Part IV). Second Printing. Stanford University Press, Stanford, California, USA.

González HH, Atkinson TH. 1984. Coccoideos asociados a árboles frutales de la región central de México. Agrociencia 57: 207–225.

Heraty JM, Polaszek A, Schauff ME. 2008. Systematics and biology of *Encarsia*, pp. 71–87 *In* Gould J, Hoelmer K, Goolsby J [eds.], Classical Biological Control of *Bemisia tabaci* in the United States. Springer Science + Business Media B. V., Dordrecht, Netherlands.

Kostarab M. 1963. The armored scale insect on Ohio (Homoptera: Coccoidea: Diaspididae). Bulletin of the Ohio Biology Survey. Columbus, Ohio, USA.

Lázaro-Castellanos C, González-Hernández H, Lomelí-Flores JR, Myartseva SN, Ortega-Arenas LD, Ochoa-Ascencio S. 2012. Enemigos naturales de escamas armadas (Hemiptera: Diaspididae) en aguacate Hass en Michoacán, México. Revista Colombiana de Entomología 38: 6–13.

McClure MS. 1990. Influence of environmental factors, pp. 319–330 *In* Rosen D [ed.], Armored Scale Insects, Their Biology, Natural Enemies and Control. Elsevier Science Publishers B.V., Amsterdam, Netherlands.

McKenzie HL. 1956. The armored scale insects of California. Volume 5. Bulletin of the California Insect Survey. University of California Press, Berkeley, California, USA.

Morse JG, Rugman-Jones PF, Watson GW, Robinson LJ, Bi JL, Stouthamer R. 2009. High levels of exotic armored scales on imported avocados raise concerns regarding USDA-APHIS' phytosanitary risk assessment. Journal of Economic Entomology 102: 855–967.

Myartseva SN. 2015. Three new species of the genus *Coccobius* Ratzeburg, 1852 (Hymenoptera: Aphelinidae) from Mexico. Russian Entomological Journal 24: 243–246.

Myartseva SN, Evans G. 2007. Genus *Encarsia* Foster of Mexico (Hymenoptera: Chalcidoidea: Aphelinidae) – A revision, key and description of new species. Primera edición. Departamento de Fomento Editorial, Universidad Autónoma de Tamaulipas. Ciudad Victoria, Tamaulipas, México.

Myartseva SN, González-Hernández A. 2007. *Encarsia citrina* (Craw) (Hymenoptera: Aphelinidae), un parasitoide de las escamas armadas (Homoptera: Diaspididae) en México. Folia Entomológica Mexicana 46: 101–106.

Myartseva SN, Ruíz-Cancino E, Coronado-Blanco JM. 2010. El género *Aphytis* Howard (Hymenoptera: Chalcidoidea: Aphelinidae) en México, clave de especies y descripción de una especie nueva. Dugesiana 17: 81–94.

Myartseva SN, Ruíz-Cancino E, Coronado-Blanco JM. 2016a. Two new species of the genus *Coccobius* Ratzeburg, 1852 (Hymenoptera: Chalcidoidea: Aphelinidae) from Mexico. Zoosystematica Rossica 25: 165–172.

Myartseva SN, Ruíz-Cancino E, Coronado-Blanco JM. 2016b. Conocimiento actual de los enemigos naturales (Hymenoptera: Aphelinidae) de escamas armadas (Hemiptera: Diaspididae) en México y descripción de una especie nueva de *Coccobius*. Acta Zoológica Mexicana 32: 81–89.

Noyes JS. 1982. Collecting and preserving chalcid wasps (Hymenoptera: Chalcidoidea). Journal of Natural History 16: 315–334.

Noyes JS, Woolley JB, Zolnerowich G. 1997. Encyrtidae, pp. 170–320 *In* Gibson GAP, Huber JT, Woolley JB [eds.], Annotated Key to the Genera of Nearctic Chalcidoidea (Hymenoptera). NRC Research Press, Ottawa, Canada.

Prinsloo GL. 1995. Revision of the southern African species of *Coccobius* Ratzeburg (Hymenoptera: Aphelinidae), parasitoids of armoured scale insects (Homoptera: Diaspididae). Journal of Natural History 29: 1517–1541.

R Core Team. 2015. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org (last accessed 2 Mar 2021).

Ramírez-Ahuja ML, Dal Molin A, González-Hernández A, Woolley JB. 2015. Sinopsis y clave para la identificación de las especies de *Signiphora* (Hymenoptera: Signiphoridae) de México, con notas sobre biología y distribución. Revista Mexicana de Biodiversidad 86: 337–347.

Rosen D. 1973. Methodology for biological control of armored scale insects. Phytoparasitica 1: 47–54.

SIAP – Sistema de Información Agroalimentaria y Pesquera. 2018. Cierre de Producción Agrícola. Anuario Estadístico de la Producción Agrícola. https://nube.siap.gob.mx/cierreagricola/ (last accessed 4 Mar 2021).

Stocks IA, Evans GA. 2017. Armored scales (Hemiptera: Diaspididae) infesting Hass avocado intercepted in Florida and new parasitoid-host association for *Davidsonaspis aguacatae*. Florida Entomologist 100: 491–494.

Wang ZH, Huang J, Polaszek A. 2014. Three new species of *Coccobius* Ratzeburg (Hymenoptera, Aphelinidae) and redescription of *C. abdominis* Huang and *C. furviflagellatus* Huang from China. Zootaxa 3774: 460–472.

Wooley JB, Dal Molin A. 2017. Taxonomic revision of the *Flavopalliata* species group of *Signiphora* (Hymenoptera: Signiphoridae). Zootaxa 4315: 1–150.