N O T E

Diversity of Thrips (Thysanoptera) Associated with Avocado Orchards in Central Veracruz México[1]

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Mexico is the main producer and exporter of avocado, *Persea americana* Mill., representing >30% of the world harvest. The production value in 2017 was an estimated US$1.9 billion, with >2,000 tons of harvested fruit. Because of the increase in the global demand for avocado, the area planted in avocado in Mexico has increased to approximately 218,000 ha in 27 states (SIAP 2019; https://nube.siap.gob.mx/cierreagricola/; accessed 18 April 2019). In the last 10 years, the increase in avocado planted has largely occurred in Veracruz State, particularly in the central area where climatic conditions are suitable for the avocado production (SIAP 2019, https://www.gob.mx/siap/documentos/boletin-mensual-de-avances-de-la-produccion-de-aguacate-103935; accessed 19 April 2019). Production in Veracruz state in 2017 was 6,550 tons, representing the third Mexican state with the highest increment in its plantings of avocado (SEDARPA 2019, http://www.veracruz.gob.mx/agropecuario/cierre-2017-estadisticas-agricolas/; accessed 29 April 2019).

One of the main issues for the production and commercialization of avocados in Mexico is the control of the high numbers of phytophagous thrips (Bravo-Pérez et al. 2018, J. Integr. Agric. 17: 2509–2517). Feeding and oviposition by these insects injure leaves, flowers, and fruits, causing malformations in young avocado fruits by damaging the epidermis. Eventually, the lesions become large pale or brown areas in the fruit epidermis that reduce the commercial value (Hoddle et al. 2002, Calif. Agric. 56: 103–107). In Mexico, studies to determine thrips species associated with avocado trees have focused on the states with the highest production, such as Michoacán, Nayarit, and Estado de México. Damage caused by thrips has been detected in avocado orchards in Veracruz state; however, the thrips species associated with avocado in this area are not yet known.

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In this work, the identity and population density of thrips species on floral and foliar buttons of avocado trees were determined in two orchards in the Xico locality in the central area in Veracruz state. Sampling was conducted between February and October 2018, in the El Clavito orchard (total area, 15 ha; N 19°24′58′′ and W 97°02′28′′) at 1,537 meters above sea level (masl) and in the Arroyo Seco orchard (total area, 20 ha; N 19°24′43′′ and W 97°03′58′′) at 1,758 masl. Both orchards are planted with 8-yr-old 'Hass' avocado trees. The climate in Xico locality is semiwarm wet with rain year-round, with an average temperature of 18 to 20°C and a mean annual rainfall of 2,000 mm (INEGI 2019, http://www.beta.inegi.org.mx/temas/mapas/climatologia/; last accessed 22 April 2019).

In each orchard, 10 trees were randomly selected in a zig-zag pattern. When sampling was initiated, each tree was marked with fluorescent flagging tape to use the same trees in the sampling process throughout the study. The samples were taken from the low strata (1–2 m above ground) and high strata (3–4 m above ground) of the tree canopy at each of the four cardinal points in each stratum. Thrips were collected directly from the buds or inflorescences by spraying soap solution (1:40, v/v) six times in each sample point in the canopy. The soap solution containing the thrips was collected in 50-ml Falcon tubes and transported to the laboratory for processing. Thrips were recovered by filtering the soap solution from each tube through a sieve (150-μm mesh). The mesh was then washed, and the thrips were transferred to 70% ethanol. Before thrips identification, each specimen was cleared as described by Bravo-Pérez et al. (2018) and mounted on glass slides with Canada balsam. The specimens were examined microscopically (100× and 400×) and identified by the first author based on taxonomic keys (Mound and Marullo 1996, Mem. Entomol. Int. 6: 1–488; Mound and Kibby 1998, Thysanoptera an Identification Guide, CAB International, U.K.; Lima and Mound 2016, Zootaxa 4162: 1–45). A multivariate analysis of variance based on permutations (PERMANOVA) was used to assess the difference in the number each thrips species among orchards and sampling times (months). To perform the PERMANOVA analysis, a Bray–Curtis dissimilarities matrix was previously calculated considering the relative abundance of each thrips species in all samples. The significance threshold for PERMANOVA was set at $P < 0.001$. When PERMANOVA was significant, differences between samples were determined with multiple pairwise comparisons using a Wilcoxon test with false discovery rate correction.

In total, 790 adults representing 5 genera and 16 species were collected in both orchards over the course of this study. The most abundant species was *Frankliniella gardeniae* Moulton followed by *Scirtothrips perseae* Nakahara and *Frankliniella invasor* Sakimura (Table 1). According to the literature, this is the first record of *Frankliniella annulipes* Reuter and *Frankliniella schultzei* Trybom associated with avocado trees. However, they can be considered as occasional visitors in the agroecosystem due to the low abundance in which they were found. In the overall statistical analysis, no significant difference was found in the population of thrips between the two orchards ($F = 1.5846$; df $= 1$; $P = 0.175$). However, a seasonal difference was found due to the population flow in the different sampling months ($F = 7.2897$; df $= 8$; $P = 0.001$). In addition, in each orchard, specific statistical differences were detected in the population density of *F. gardeniae* and *S. perseae* in some months of sampling ($F = 2.9421$; df $= 8$; $P = 0.002$). The largest numbers of specimens in both orchards were collected during

Table 1. Relative abundance of thrips species associated with avocado trees in Xico, Veracruz.

Species	El Clavito		Arroyo Seco	
	No.	Relative Abundance (%)	No.	Relative Abundance (%)
Frankliniella gardeniae	287	66.74	146	62.66
Scirtothrips perseae	109	25.35	43	18.45
Frankliniella invasor	20	4.65	17	7.30
Frankliniella insularis	6	1.40	6	2.58
Frankliniella gemina	3	0.70	3	1.29
Neohydatothrips signifer	1	0.23	4	1.72
Frankliniella occidentalis	1	0.23	3	1.29
Frankliniella cephalica	1	0.23	NF[a]	NF
Frankliniella fallaciosa	1	0.23	3	1.29
Frankliniella bruneri	NF	NF	2	0.86
Frankliniella tritici	NF	NF	2	0.86
Frankliniella fulvipes	NF	NF	1	0.43
Frankliniella annulipes	NF	NF	1	0.43
Frankliniella schultzei	NF	NF	1	0.43
Aeolothrips mexicanus	NF	NF	1	0.43
Franklinothrips lineatus	1	0.23	NF	NF
No. of species	10		14	

[a] NF = species not found.

spring flowering between February and April 2018, with 471 (90.2%) in El Clavito and 212 (79.1%) in Arroyo Seco. In El Clavito, the *F. gardeniae* population was significantly higher in February ($W = 40.3$; $P = 0.03$), March ($W = 40.3$; $P = 0.04$), and April ($W = 40.3$; $P = 0.01$) where 4.2, 8.8, and 23.6 individuals per sample were collected, respectively. No *F. gardeniae* specimens were found in June, July, and October. Likewise, *S. perseae* was most numerous in February ($W = 40.3$; $P = 0.01$) and March, with 6.6 and 3 individuals per sample, respectively. Although in low abundance, *S. perseae* was recorded in all of the samplings (Fig. 1). The population of *F. gardeniae* was significantly higher in February ($W = 40.3$; $P = 0.01$), March ($W = 40.3$; $P = 0.02$), April ($W = 40.3$; $P = 0.01$), and July ($W = 40.3$; $P = 0.04$) in Arroyo Seco where 7.3, 5.4, 6.5, and 3.5 individuals per sample were collected, respectively. By contrast, no *S. gardeniae* were found in May, June, August, and September. The population of *S. perseae* was significantly higher in August (3.1

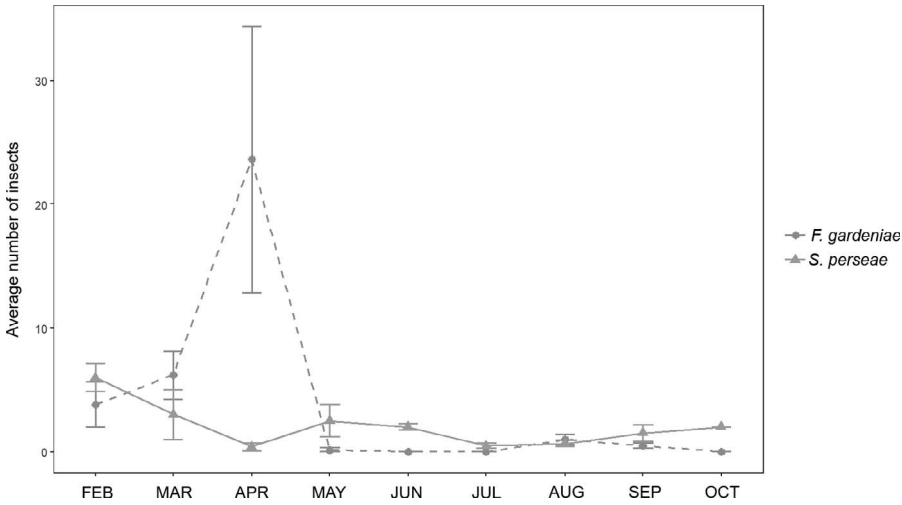

Fig. 1. Thrips per sample associated with *P. americana* flowers and buds in El Clavito orchard (Xico locality, Veracruz state, Mexico).

individuals per sample $W = 40.3$; $P = 0.01$) than in the flowering period in February, March, and April when one individual was found per sample. Nevertheless, *S. perseae* was found during almost all the sampling except for July (Fig. 2).

Despite the economic importance that avocado farming has in Mexico and the phytosanitary problems associated with thrips, there are few studies that document the diversity of thrips species associated with this crop. This is the first work in which

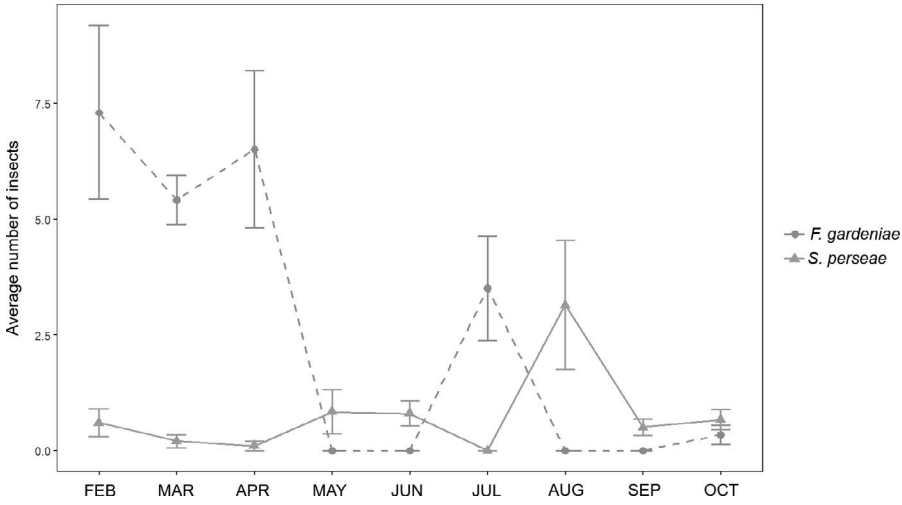

Fig. 2. Thrips per sample associated with *P. americana* flowers and buds in Arroyo Seco orchard (Xico locality, Veracruz state, Mexico).

thrips species associated with avocado are identified in Veracruz state. One of the main harmful thrips for avocado is *S. perseae* (Mound and Hoddle 2016, Zootaxa 4079: 388–392). In the present work, *S. perseae* was found in lower abundance (between 18 and 25%) with respect to *F. gardeniae*; however, this species was recorded during all of the sampling months. This is likely due to *S. perseae* having a limited host range and that it does not feed on other plant species during the months when there is no flowering. In both sampling locations, *F. gardeniae* was the most abundant species, representing >60% of the abundance. This species was described for the first time in the United States associated with *Gardenia* sp. flowers in a shipment from Mexico (Moulton 1948, Rev. Entomol. 19: 55–114). Currently, *F. gardeniae* is considered as a common and widespread species in Latin America associated with aromatic flowers (Cavalleri and Mound 2012, Zootaxa 3270: 1–30). Also, *F. gardeniae* has been registered as a mango pollinator in Costa Rica (Retana-Salazar and Rodriguez-Arrieta 2015, Rev. Gaditana Entomol. 6: 103–112) and as a pest of *Vitis vinifera* L. causing damage to fruits in Brazil (Nunes Moreira et al. 2014, Cienc. Agrotecnol. 38: 328–334). In Colombia, high populations of *F. gardeniae* associated with avocado trees have been recorded; thus, it is considered as an emerging pest (Echeverri et al. 2004, Rev. Fac. Nac. Agron. Medellin 57: 2178–2189). In Mexico, *F. gardeniae* is not considered an important pest of avocado due to its low relative abundance, although it has been previously reported as associated with avocado trees in the states of Nayarit, Michoacán, and Mexico (Bravo-Perez et al. 2018; Cambero-Campos et al. 2011, Fla. Entomol. 94: 982–986). Herein, we conclude that *F. gardeniae* may be the causative agent of the damage currently attributed to thrips in avocado orchards studied in the Xico locality of Veracruz state.

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