

Population Fluctuation and Altitudinal Distribution of *Tetraleurodes perseae* (Nakahara) (Hemiptera: Aleyrodidae) in Avocado (Lauraceae) in Morelos, Mexico

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Abstract

Although whiteflies *Tetraleurodes perseae* (Nakahara) (Hemiptera: Aleyrodidae) are considered a secondary pest of avocado crops, their presence and the damages that they cause can decrease crop vigor and affect production. The objective of the present work was to determine the population fluctuation and altitudinal distribution of the *T. perseae* Nakahara whitefly in avocado trees, as well as to determine the number of possible generations in one year. The study was done in three orchards in Morelos state, located at different altitudes, from February 2014 to April 2015. Samplings were done every 21 days from 10 randomly chosen trees in each orchard. The samples were taken randomly from the middle stratus (1.6 m in height) of each tree; in buds or young leaves for the number of adults and leaves only for nymphs. Additionally, two yellow traps (7 × 14 cm) with glue were placed in each tree for adult samplings. Data were collected regarding vegetative budding, rainfall, relative humidity, and temperature. *T. perseae* was present in all three sampled orchards, with a greater presence in the lowest orchard, during the whole study period. In the orchard with the lowest altitudinal gradient (1,736 masl), 11 whitefly generations developed; 10 generations developed in the medium gradient orchard (1,934 masl); and 8 generations developed in the highest orchard (2,230 masl). The adults showed a positive relationship with regard to vegetative buds, while the nymphs had a negative relationship with regard to relative humidity. The rest of the parameters showed diverse effects on the species depending on the altitude of the orchard.

Resumen

Las moscas blancas (Hemiptera: Aleyrodidae), aunque son consideradas plagas secundarias en el cultivo de aguacate, su presencia y daño puede reducir el vigor y afectar la producción de éste. El objetivo del presente trabajo fue conocer la fluctuación poblacional y distribución altitudinal de la mosca blanca *Tetraleurodes perseae* Nakahara en árboles de aguacate, así como determinar el número de posibles generaciones por año. El estudio se llevó a cabo en tres huertos en el estado de Morelos, situados en diferentes altitudes, en el periodo de febrero de 2014 a abril de 2015. Se hicieron muestreos cada 21 días, en 10 árboles seleccionados al azar en cada huerto. Los muestreos se hicieron al azar en el estrato medio del árbol (1.6 m de altura), en brotes u hojas jóvenes para el conteo de adultos, y solo hojas para ninfas; adicionalmente se colocaron dos trampas pegajosas amarillas (7x14 cm) por árbol para el muestreo de adultos. Complementariamente, se tomaron datos de brotación vegetativa, precipitación pluvial, humedad relativa y temperatura. *T. perseae* se presentó en los tres huertos muestreados, con mayor presencia en la parcela con menor altitud, durante todo el periodo de estudio. En el huerto con menor gradiente altitudinal (1736 msnm), se desarrollaron 11 generaciones de la mosca blanca, 10 generaciones en el huerto con gradiente medio (1934 msnm) y 8 generaciones en el huerto con mayor altitud (2230 msnm). Los adultos mostraron una relación positiva con respecto a los brotes vegetativos, mientras que para el caso de las ninfas, estas presentaron una relación negativa con respecto a la humedad relativa. El resto de los parámetros presentó diversos efectos sobre la especie según la altitud del huerto.

Key words: Aleyrodidae, avocado pests, whiteflies

Avocado (*Persea americana* Miller) belongs to the Lauraceae family, which is made up of 52 genera and around 3,500 species; this is one of the most primitive of the Magnoliidae families. The *Persea* genus is made up of 150 species distributed in the tropical and subtropical regions, especially in Asia, The Canary Islands, and the Americas, where there are 80 species (Bernal and Díaz 2005). It is grouped within three ecological groups or races: Mexican, Guatemalan, and Antillean (Garbanzo 2011).

Mexico is the main avocado producer worldwide with a cultivated surface area of 176,000 ha and a production of 1,521,000 metric tons in 2014. In that same year, Morelos state had ~4,000 ha of avocado with a production of 27,600 t and a mean yield of 8.2 t ha⁻¹ (SIAP 2015).

Among the main pest insects for this crop are suckers; fruit, seed, and branch borers; and some defoliating Lepidoptera (Bernal and Díaz 2005). Whiteflies *Tetraleurodes perseae* (Hemiptera: Aleyrodidae) are considered secondary pests for avocado crops since they only show up occasionally, although their presence and damages they cause can decrease vigor and affect production (González et al. 2000). *Tetraleurodes* is one of the largest genera, having 50 described species (Nakahara 1995), 20 of which were reported in North America (Mound and Halsey 1978).

The species *T. perseae* Nakahara is probably native to Latin America; it has been found in the Caribbean, Central America, Florida, and Mexico (Nakahara 1995). In its adult stage, it is characterized for having reddish-brown bands on its wings. Oviposition is done on the underside of young leaves and the eggs are kidney shaped. Upon emergence, the nymphs are yellow-brown during the first two instars, the first of which is the only mobile one. During the third and fourth instar, they turn black and remain immobile in their feeding places. The nymphs are characterized for having a white wax lining around their body that forms upward growing curls, besides exuvia from prior molts might accumulate on the back. This helps to determine the age of the nymphs by counting the number of accumulated exuvia. This characteristic is more frequently observed in the first three instars (Hoddle 2013).

The agricultural importance of whiteflies mainly lies in its capacity to transmit viruses that can produce plant diseases; however, they also cause direct damages by feeding on the leaves and indirect damages by favoring the development of fungi on the leaves and thus limit the photosynthetic capacity among other physiological activities (Vázquez 2004). Currently, *T. perseae* is not reported as a virus transmitting species; however, the high circulation of avocado plants increases the possibility of new viral diseases being established. Therefore, this species could be an efficient transmitter of diseases, although further studies are required to determine said transmitting capacity (Hoddle 2013).

Given the importance that this species has obtained, the present work was proposed, with the following objectives: to learn the population fluctuation and altitudinal distribution of the *T. perseae* whitefly in avocado trees in Morelos state, Mexico, as well as to determine the number of generations that it develops per year. This information will provide a basis to implement specific handling of the species.

Materials and Methods

Location of the Study Area

The study was done in three orchards of Morelos state, located at different altitudes, from February 2014 to April 2015. The first

orchard (Tlayacapan) is representative of a low altitudinal gradient (1,736 masl) and is located in the community of Tlayacapan, municipality of Tlayacapan (N 18° 58' 44.03" W -98° 59' 32.44"). The second orchard (Tlalnepantla B) is representative of a medium altitudinal gradient (1934 masl) and is located in the municipality of Tlalnepantla (N 19° 00' 08.78 W -98° 59' 26.72"). The third orchard (Tlalnepantla A) is representative of a high altitudinal gradient (2230 masl) and is located in the municipality of Tlalnepantla (N 19° 01' 08.54" W -98° 59' 53.63"). The orchards used for sampling had a mean age of 10 years, and were planted with Hass avocado variety in reproductive age. The three orchards have conventional handling with minimum or null pesticide application.

Species Identification

Nymphs in the fourth instar and adults of the species were collected, placed in 70% alcohol and transported to the Entomology Laboratory in the Colegio de Postgraduados, where they were processed and identified. Corroboration of the species was done by the specialist in the Aleyrodidae taxonomic group, Dr. Vicente Emilio Carapia Ruiz, of the Universidad Autonoma del Estado de Morelos.

Abundance and Population Fluctuation

To determine the population fluctuation of *T. perseae* adults and nymphs, samplings were done every 21 days in each orchard from February 2014 to April 2015. Ten randomly chosen trees from each orchard were sampled. In each tree, 10 young buds (according to the phenological stage) or young leaves were assessed for adults, and 10 leaves for nymphs. The samples were taken randomly from the middle stratus (1.6 m in height) of the trees and in the early hours of the day when adults are less mobile to avoid underestimation, the count was done directly on the trees. Additionally, two yellow sticky traps (7 × 14 cm) were placed in each tree to sample adults. The traps were placed in previously labeled polyethylene bags and transported to the Entomology Laboratory of the Colegio de Postgraduados for later counting. The adults captured in the traps were counted with a Nikon stereoscopic microscope (Model SMZ800, Melville, NY).

Environmental Variables

The environmental variables studied were rainfall, relative humidity, and temperature. The data were obtained with datalogger Extech (Model RHT10, Nashua, NH) equipment located on a central shaft of each orchard at a height of 2.0 m, scheduled to take registration variables every 60 min during the day and night, and complemented with information from the Agroclimatic Station Network of the National Institute of Forestry, Agricultural and Animal Husbandry Research (Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias). The relationship between the environmental variables and the population densities obtained during the sampling dates were studied.

Given that the thermal requirement (heat unit, HU) to complete a defined biological cycle for the species is unknown, the mean requirement for the main species in the area of study was used as reference; these species are: *Trialeurodes vaporariorum* Westwood (380.70 HU) (Osborne 1982), *Bemisia tabaci* Gennadius (317.3 HU) (Ahn et al. 2001), and *Bemisia argentifoli* Gennadius (319.70 HU) (Greenberg et al. 2000). According to the thermal requirement established by each author, the number of completed generations through the accumulation of HUs was estimated in order to identify the seasons with the most favorable thermal conditions for the development of the

pest. The thermal requirement used for *T. perseae* was 339.2 HU with a lower threshold temperature of 10°C (Murray 2008).

Statistical Analysis

A Poisson model was fitted using the population data for nymphs and adults; the relationship with vegetative buds, precipitation, relative humidity, and temperature were studied in all three orchards. The data were processed using SAS software (Poisson model, SAS Institute Inc. 2002). With the compiled information on temperature conditions in each orchard, the HUs were calculated based on the methodology described by Allen (1976).

Results

The species present in all three avocado orchards was identified as *T. perseae* (Nakahara) (Hemiptera: Aleyrodidae: Aleyrodinae).

Abundance and Population Fluctuation

In the yellow trap count done for the Tlayacapan orchard (1,736 masl), a total of 2009 adults was obtained in the whole sampling period, while in the direct sampling from buds 1,034 adults were obtained, and 3,992 nymphs were obtained from the leaves. In the Tlalnepantla B orchard (1,934 masl) 852 adults in the yellow traps,

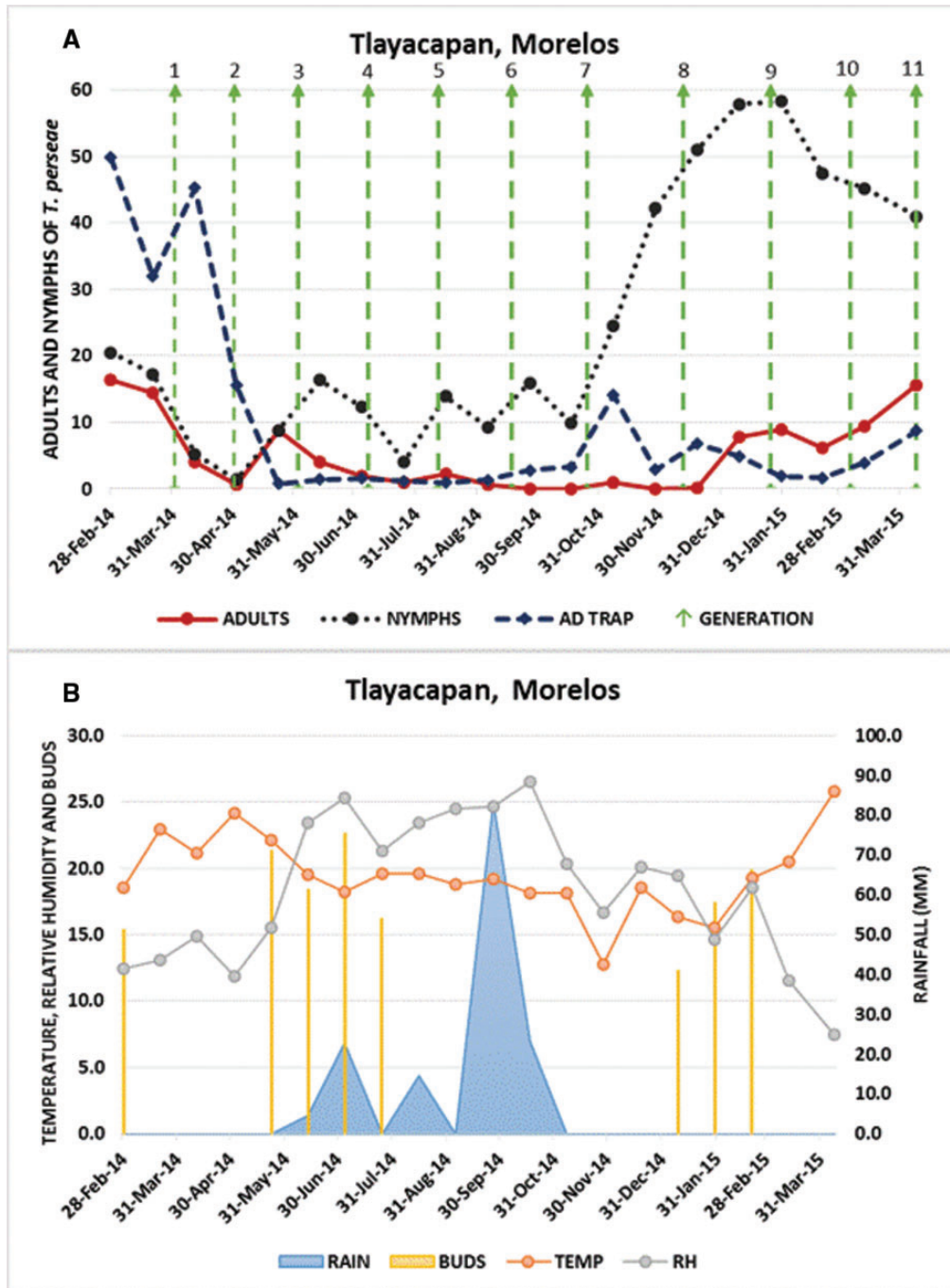


Fig. 1. Population fluctuation of *T. perseae*, crop buds and meteorological data from February 2014 to April 2015 in the Tlayacapan orchard (1,736 masl). (A) Adult fluctuation in traps and leaves, nymphs fluctuation and number of generations; (B) Mean temperature, precipitation, relative humidity, and vegetative buds.

Table 1. Average whitefly populations for *T. perseae* during February 2014 to April 2015 in three avocado orchards in Morelos, Mexico

Date	Tlayacapan 1,736 masl			Tlanepantla B 1,934 masl			Tlanepantla A 2,230 masl		
	AD	NY	AD TR	AD	NY	AD TR	AD	NY	AD TR
28 Feb. 2014	16.4	4.1	49.8	8.2	7.2	12.0	3.1	8.8	27.4
21 Mar. 2014	14.5	2.8	32.0	4.7	4.5	14.7	8.2	9.5	12.3
11 Apr. 2014	4.1	1.1	45.3	1.5	2.1	21.2	6.6	3.5	42.9
2 May 2014	0.7	0.7	15.6	0	0	9.7	7.9	0	6.8
23 May 2014	8.8	0	0.8	1.2	0	1.3	5	0	1.5
13 Jun. 2014	4	12.4	1.4	1.9	2.3	1.8	1.4	1.5	1.1
4 Jul. 2014	1.9	10.4	1.6	1.6	2.5	0.9	2.4	7.9	2.9
25 Jul. 2014	1	3.1	1.2	3.9	2.3	1.1	1.6	2.5	2.5
15 Aug. 2014	2.3	11.6	0.9	1.4	10.9	1.5	1.3	6.3	2.9
5 Sep. 2014	0.7	8.6	1.3	5.9	14.5	1.9	6.2	19.9	1.4
26 Sep. 2014	0	16	2.8	6.6	12.5	2.2	2	5.4	1.6
17 Oct. 2014	0	9.9	3.3	0	1	2.5	0.8	5.4	2.6
7 Nov. 2014	1	23.5	14.1	0	3.9	1.4	1.3	3.9	1.3
28 Nov. 2014	0	42.2	2.9	0	9	1.6	0	11.2	0.9
19 Dec. 2014	0.2	50.8	6.8	0	10.7	5.0	0	12.5	4.3
09 Jan. 2015	7.8	50.1	4.9	2.1	14.9	3.9	1.2	14.7	1.1
30 Jan. 2015	8.9	49.4	1.9	10.2	9.9	3.6	5.5	16.1	3.8
20 Feb. 2015	6.1	41.3	1.7	5.6	9.1	2.5	8.7	10.4	1.4
13 Mar. 2015	9.4	35.8	3.9	7.3	8.8	3.8	8.5	7.6	5.2
08 Apr. 2015	15.6	25.4	8.7	13.8	9.3	4.6	7.3	7.1	7.5

AD, adults; NY, nymphs; AD TR, adults for tramp.

759 adults from buds, and 1,354 nymphs from leaves were counted. Last, in the Tlanepantla A orchard (2,230 masl) a total 1,314 adults in traps, 790 adults from buds, and 1,542 nymphs from leaves were obtained.

T. perseae was present in all three sampled orchards. The results indicated that the lowest altitude orchard had the highest population of the species (Fig. 1, Table 1), from a greater capture registry in yellow traps and direct counting from buds and leaves, with a ratio of 1:3.9 (adult:nymph). The medium altitude orchard had a similar proportion of adults captured in the traps and counted from buds (Fig. 2, Table 1), while the nymph population was greater than the adult population with an adult:nymph ratio of 1:1.8. The orchard with the highest altitude showed a lower population of adults in the direct count from buds than in the traps (Fig. 3, Table 1); the ratio of adults from buds with regard to nymphs from leaves was 1:2.

The population fluctuation study of *T. perseae* showed that the species was present during the whole sampling period (February 2014 to April 2015) in at least one of its biological stages. The capture of adults in the yellow traps was greater at the beginning of the sampling and showed a definite decrease in the month of May in all three orchards; however, there were captures during the whole study period. The sampling of adults from leaves revealed that the population decreased in all three orchards during the rainy season and the colder months (June 2014 to January 2015), followed by an increasing tendency with the rising temperatures from January 2015 onwards. An inverse behavior was observed with regard to nymph density; there was an increase during the colder period (November 2014 to January 2015). This effect was most evident in the lower altitude orchard.

In the case of the low altitude orchard (Tlayacapan) (Fig. 1A), there was a high capture of adults in the yellow traps. The registry was 50 adults per trap at the beginning of the sampling (February 2014). Later, the capture was under 5 adults per trap, with a population peak (14 adults per trap) in October, and finally a rising tendency by the end of the sampling period (March–April 2015).

Contrarily, there was an initial mean of 17 adults on leaves and a decreasing tendency in April, a population peak in May, and a total mean of about one individual per bud from May through December 2014. After this, the population showed an increasing tendency. The nymphs had greater populations than the adults on leaves during the study period. Their population showed fluctuations from February to October 2014, followed by a considerable increase (50 nymphs per leaf) until February 2015, after which there was a decreasing tendency until the end of the study.

In the medium altitude orchard (Tlanepantla B) (Fig. 2A), the adult population captured in the traps showed a population peak in April 2014 and then the population density decreased considerably until it stabilized at fewer than five adults per trap. Contrarily, the adults counted on the leaves showed a decrease at the beginning of the sampling and a population peak in August and September. The population showed an increasing tendency from January until the end of the sampling period. The nymph count showed a similar trend to that of the adults on the leaves; however, their densities in both population peaks (August–September and November–January) were greater and their population remained constant throughout the last months of the study.

The highest altitude orchard (Tlanepantla A) (Fig. 3A) showed a high population of *T. perseae* adults during the first months of sampling with yellow traps until the month of April, when there was a marked population decrease. There was a population peak between August and September, while the population decreased to its lowest point from November to January after the increasing tendency. The adults counted on the leaves had a population peak in March, April, and August, and from January onwards. The nymphs showed population peaks in February, March, June, August, September, and from November to January; this last was contrary to the adults.

Generations Obtained from Calculating HU

The results of calculating the HUs indicated that in the low altitude gradient orchard (1,736 masl), exactly 11 generations were

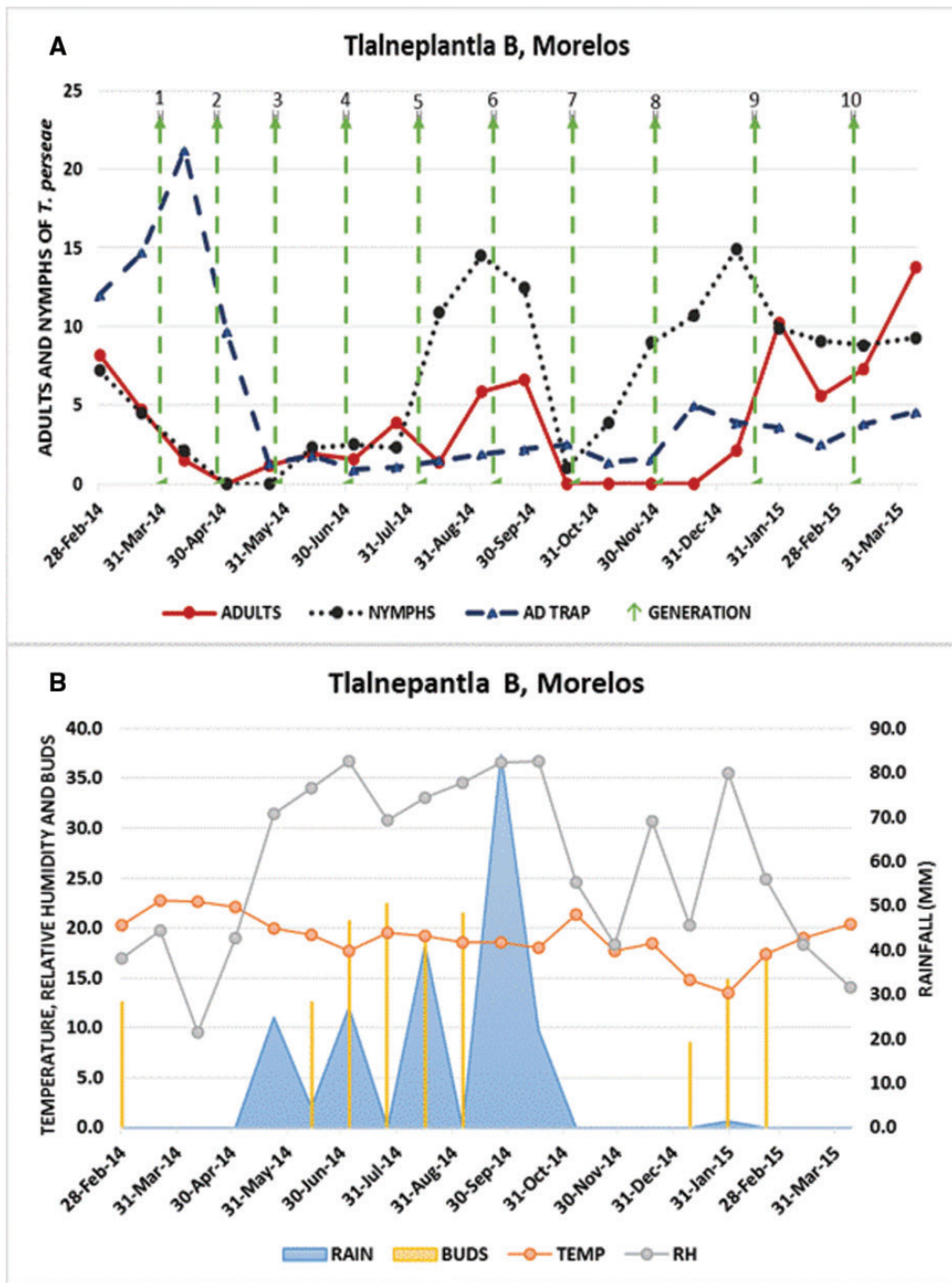


Fig. 2. Population fluctuation of *T. perseae*, crop buds and meteorological data from February 2014 to April 2015 in the Tlalnepantla B orchard (1,934 masl). (A) Adult fluctuation in traps and leaves, nymphs fluctuation and number of generations; (B) Mean temperature, precipitation, relative humidity, and vegetative buds.

completed in the 432 days of sampling (Fig. 1A). The shortest generations were obtained between 2 March and 2 June 2014; each with a duration of 31 days. The longest generation was from 26 October to 12 December 2014, which lasted 48 days. The mean generation period was 36.9 days.

In the middle gradient orchard (1,934 masl), 10 generations of *T. perseae* were completed from 28 February 2014 to 8 March 2015, while in the rest of the period only 281 HU were fulfilled, insufficient for an additional generation of this species (Fig. 2A).

In the Tlalnepantla B orchard, the shortest generation lasted 28 days, between 4 March and 27 April 2014. The longest generation was between 1 December 2014 and 18 January 2015, with a duration of 49 days. The mean generation period for this orchard was 37.4 days.

The highest altitude orchard (2,230 masl) was the one that registered the fewest generations in the study period, with only eight generations, of which, the longest one developed from 27 November 2014 to 8 February 2015, accumulating 73 days (Fig. 3A).

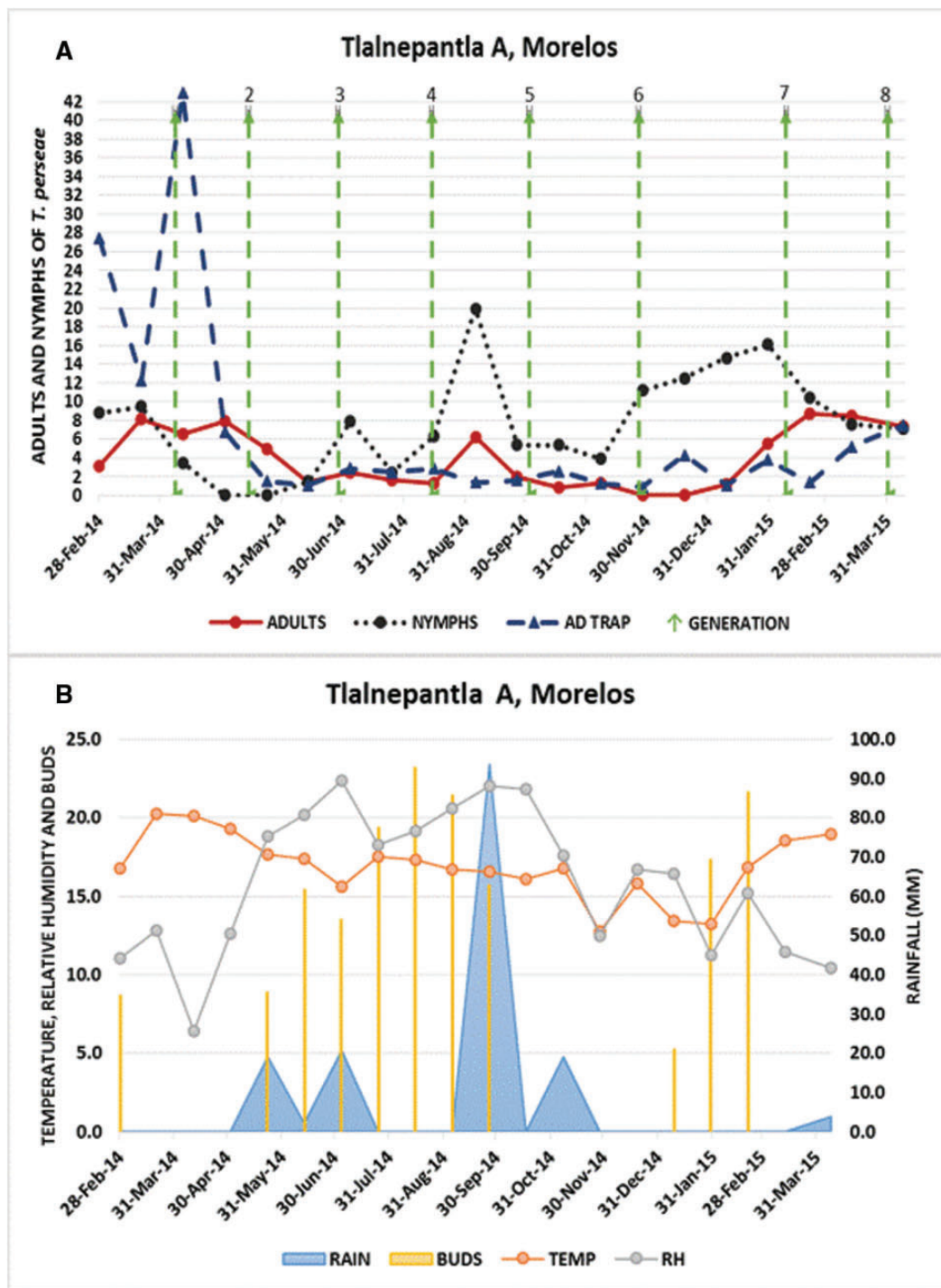


Fig. 3. Population fluctuation of *T. perseae*, crop buds and meteorological data from February 2014 to April 2015 in the Tlalnepantla A orchard (2,230 masl). (A) Adult fluctuation in traps and leaves, nymphs fluctuation and number of generations; (B) Mean temperature, precipitation, relative humidity, and vegetative buds.

The shortest generation was completed in 37 days, between 8 March and 14 May 2014. A mean of 49.9 days were required for each generation of *T. perseae* in the Tlalnepantla A orchard.

Poisson Model for Correlation Analysis

Table 2 shows the results of the Poisson model to estimate the different parameters in all three avocado orchards. The estimator

obtained for each parameter is shown, as well as the intercept, standard error, and value probability (*P*) associated with the values observed in the Chi-square statistical test.

Based on the statistical results, the following models were obtained: for the low altitudinal gradient orchard (1,736 masl) (AD TRAP) $\text{Log}(\lambda) = 4.9643 - 0.0318 p - 0.0253 t - 0.0363 h - 0.0205 b$, (AD) $\text{Log}(\lambda) = 3.7044 - 0.0452 p + 0.0123 t - 0.0502 h + 0.0504 b$, (NI) $\text{Log}(\lambda) = 7.0627 - 0.0054 p - 0.1716 t - 0.0132 h -$

Table 2. Parameters estimated with the Poisson model in the sampling of *T. perseae* for the number of adults counted in yellow traps, adults and nymphs on leaves, in three "Hass" avocado orchards in Morelos, Mexico

Trap	Tlayacapan			Tlalnepantla B			Tlalnepantla A		
	Estimation	SE	P > ChiSq	Estimation	SE	P > ChiSq	Estimation	SE	P > ChiSq
Intercept	4.9643	0.7502	<0.0001	-0.5626	1.5394	0.7148	1.8325	1.1347	0.1063
PREC	-0.0318	0.0288	0.2687	-0.011	0.0213	0.6052	0.0111	0.0371	0.7648
TEMP	-0.0253	0.0258	0.3254	0.1581	0.0648	0.0147	0.1629	0.0538	0.0025
HR	-0.0363	0.0061	<0.0001	-0.0174	0.0087	0.046	-0.0546	0.0071	<0.0001
BUDS	-0.0205	0.0095	0.0309	-0.0326	0.0194	0.0942	0.022	0.0159	0.1661
Adults	Estimation	SE	P > ChiSq	Estimation	SE	P > ChiSq	Estimation	SE	P > ChiSq
Intercept	3.7044	1.0674	0.0005	4.8377	1.2654	0.0001	-1.4459	1.4889	0.3315
PREC	-0.0452	0.0662	0.4943	0.0285	0.017	0.0936	0.0015	0.0298	0.961
TEMP	0.0123	0.0372	0.7418	-0.1166	0.0542	0.0314	0.2214	0.072	0.0021
HR	-0.0502	0.0093	<0.0001	-0.0303	0.0097	0.0019	-0.0226	0.0086	0.0087
BUDS	0.0504	0.0127	<0.0001	0.0385	0.0171	0.0242	0.0386	0.0171	0.0237
Nymphs	Estimation	SE	P > ChiSq	Estimation	SE	P > ChiSq	Estimation	SE	P > ChiSq
Intercept	7.0627	0.4063	<0.0001	6.3023	0.9118	<0.0001	4.9841	0.6834	<0.0001
PREC	-0.0054	0.0126	0.6686	0.0285	0.0114	0.0123	-0.0296	0.0222	0.1825
TEMP	-0.1716	0.0163	<0.0001	-0.1888	0.0396	<0.0001	-0.1651	0.0377	<0.0001
HR	-0.0132	0.0038	0.0005	-0.0194	0.007	0.0057	-0.0048	0.0055	0.3795
BUDS	-0.0043	0.0058	0.4566	0.0181	0.0126	0.1509	0.016	0.0098	0.1009

0.0043 b; for the medium altitudinal gradient orchard (1,934 masl) (AD TRAP) $\text{Log}(\lambda) = -0.5626 - 0.011 p + 0.1581 t - 0.0174 h - 0.0326 b$, (AD) $\text{Log}(\lambda) = 4.8377 + 0.0285 p - 0.1166 t - 0.0303 h + 0.0385 b$, (NI) $\text{Log}(\lambda) = 6.3023 + 0.0285 p - 0.1888 t - 0.0194 h + 0.0181 b$; and for the high altitudinal orchard (2,230 masl) (AD TRAP) $\text{Log}(\lambda) = 1.8325 + 0.0111 p + 0.1629 t - 0.0546 h - 0.022 b$, (AD) $\text{Log}(\lambda) = -1.4459 + 0.0015 p + 0.2214 t - 0.0226 h + 0.0386 b$, (NI) $\text{Log}(\lambda) = 4.9841 - 0.0296 p - 0.1651 t - 0.0048 h + 0.016 b$. Where λ , phenological stage of *T. perseae*; p, precipitation; t = temperature in °C; h, relative humidity; and b, number of vegetative buds.

The results derived from the Poisson model showed that adults sampled with yellow traps in the low altitude orchard (Tlayacapan), there was a negative relationship of capture with regard to the four parameters evaluated (Fig. 1B). The adults sampled from the avocado leaves showed statistical significance with regard to temperature and number of vegetative buds. With respect to nymphs, no parameter was significant in the resulting model.

In the Tlalnepantla B orchard, there was a positive relationship between temperature and adults captured in the traps (Fig. 2B). Rainfall and vegetative buds showed a positive relationship in the adult model, while temperature and relative humidity had a negative relationship with the presence of nymphs.

In the highest altitude orchard (Tlalnepantla A), the model showed no statistical significance with regard to relative humidity, but did so with the rest of the parameters evaluated (Fig. 3B). Three parameters were significant (Table 1) in the model with regard to the presence of adults on leaves, relative humidity being nonsignificant. Only the vegetative buds indicated a positive relationship with *T. perseae* nymphs.

Discussion

The presence of *T. perseae* was detected in all three orchards during the entire study period, thus we can infer that this species had no interference from altitude, contrary to what was found in studies regarding other pest species present in avocado, such as *Trioza aguacate* Hollis & Martin (Hemiptera: Triozidae), where the altitude gradient,

temperature, and the phenological stage of the crop favored its presence (González-Santarosa et al. 2014). However, agree with Hoddle (2006) on the same species, where *T. perseae* was present throughout the study period, with its respective fluctuations in population.

At the beginning of the study, the number of adults captured in the yellow traps was high; however, towards the middle of April, there was a significant decrease. This fact could be due to hail falling on 10 April 2014, which severely affected the foliage of the avocado trees and might have caused the decrease in the *T. perseae* adult population, as well as nymphs. This weather factor might have had a greater interference in the lower altitude orchard (Tlayacapan, 1,736 masl) than in the other two orchards since in August, the latter showed population peaks, similar to what is mentioned by Hoddle (2006), who found a population increase in the same month and which he related with young buds. This effect was also similar to our observations in adult samplings in the middle and high altitude orchards (Tlalnepantla B, 1,934 masl and Tlalnepantla A, 2,230 masl), although a greater relationship between population increase and vegetative growth in January and February was observed.

This same author (Hoddle 2006) found that *T. perseae* tends to decrease in adult population in September and October, which partially coincides with the results in this study, with the difference that low adult populations remained throughout the cold months (November–January). Conversely, nymph population density increased, which could indicate that this species goes through the winter season in nymphal stage. On the other hand, in March and April both adult and nymph populations increased in density.

In all three orchards, and based on the Poisson analysis, the adult populations had a positive relationship with the presence of vegetative buds in the crop (Tlayacapan: $\alpha = 0.0504$, $P \leq 0.0001$; Tlalnepantla B: $\alpha = 0.0385$, $P = 0.0242$; Tlalnepantla A: $\alpha = 0.0386$, $P = 0.0237$), while increments in the relative humidity negatively affected the presence of adults. Because of this, after the rainy season the population remained at low densities, and given that the adults feed on young tissues, their population increased again when new vegetative buds grew.

Nymph development had a negative relationship with temperature in all three orchards (Tlayacapan: $\alpha = -0.1716$, $P \leq 0.0001$;

Tlalnepantla B: $\alpha = -0.1888$, $P \leq 0.0001$; Tlalnepantla A: $\alpha = -0.1651$, $P \leq 0.0001$), which agrees with the results of the sampling in the cold months, where their population was greater than the adult population. Moreover, the population peaks observed in the rainy months did not indicate a negative relationship, given that the nymphs feed and develop on the back of the leaves, which provide them with refuge and protection from precipitation. This could also represent a livelihood strategy during the rainy season; however, after a period of intense rains the populations decreased significantly.

Temperature and precipitation played an important role in the population fluctuation of *T. perseae* during the dry season, when there was an increase in temperature, the population increased (February–April). In the case of rainfall, it influenced positively the decrease in the infestation, given that the greatest population decrease of *T. perseae* adults and nymphs was after a period of constant rainfall (August–September) in all three orchards.

From this, rainfall was defined as an important factor in the development of *T. perseae*, as when there was no rainfall, the populations, especially nymphs, showed a tendency to increase. Contrastingly, during and after the period of most rainfall, the populations of both biological stages significantly decreased in density. This proves the fluctuation of the species in all three orchards. These results are similar to those found by González-Santarosa et al. (2014) for *T. aguacate*, where the psyllid populations decreased with an increase in rainfall.

González-Santarosa et al. (2014) also determined that the absence of vegetative buds was a limiting factor for *T. aguacate* populations. In this sense, the results of the present evaluation showed a similar tendency; given that *T. perseae* adults preferably feed on the buds, there was a significant decrease of both adults and nymphs when there was no growth of vegetative buds in the orchards.

The weather conditions, mainly temperature, allowed us to determine that *T. perseae* completed at least eight generations in the highest altitude orchard, ten generations in the middle altitude orchard, and eleven generations in the low altitude orchard. These results were contrary to what is suggested by Hoddle (2006), who indicated that this species could be univoltine in avocado orchards in California, USA. However, this same author reported that the generational timeframe from egg to adult was 43–46 days at a mean temperature of 25°C (Hoddle 2006, 2013). The results were more closely related with the results of Dowell (1982), who estimated eight generations per year for *Tetraleurodes acaciae* (Hemiptera: Aleyrodidae) in *Calliandra hematocephala* in Florida; a whitefly species native to Mexico and California.

Bellows et al. (1998) carried out a study to know the biology of *Paraleyrodes minei* (Hemiptera: Aleyrodidae) in Southern California, USA, from where they determined differences in the fluctuation of the pest species in orange orchards (*Citrus sinensis*). *P. minei* had higher population densities in the summer samplings than in the winter samplings. They also determined that the lifecycle was shorter (20 days) in the summer and longer in the winter (60 days), as well as a greater pre-imaginal survival in summer (36%). They found no diapause stage in their study period.

The *T. perseae* samplings also showed no diapause period in this species; however, the population fluctuations observed allowed to define that the nymph population is more abundant than the adults in the winter, as there were almost no adults in the field during this period.

Knowing the fluctuation of *T. perseae*, resulting from the present study, gives a basis to learn the biology of this species. Moreover, the data generated can be used for integral pest management programs in avocado orchards, as a reference for decision making and to make efforts in its control more efficient.

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