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Effect of temperature and rainfall on the population dynamics of *Frankliniella occidentalis* and its natural enemies in Mexican lemon

Efecto de la temperatura y la precipitación pluvial en la dinámica poblacional de *Frankliniella occidentalis* y sus enemigos naturales en Limón mexicano

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ABSTRACT

Frankliniella occidentalis (Pergande) is one of the most important pests affecting Mexican lemon crops in Michoacán, and its control is primarily based on the use of broad-spectrum insecticides. However, currently, thrips populations have remained constant in orchards. To understand the influence of atmospheric factors on the population dynamics of the pest and its natural enemies, the density of thrips populations (Thysanoptera: Thripidae) and their natural enemies was correlated with temperatures (minimum, average, and maximum) and precipitation, over four years. A significant correlation was found between the population density of *F. occidentalis* and both the average and maximum temperatures, while a positive correlation was observed between the population density of natural enemies and both precipitation and minimum temperature. These findings highlight the impact of environmental factors on the regulation of thrips populations and beneficial organisms. Obtained data suggest that future conditions may lead to an increase in thrips populations and a decline in beneficial insect populations in the citrus-growing region of the Apatzingán Valley. Therefore, a change in the current phytosanitary management approach is necessary, and an integrated management strategy is proposed to enhance the role of natural enemies in biological pest control.

KEY WORDS: Mexican lemon, pest, thrips, IPM (Integrated Pest Management), pest control.

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RESUMEN

Frankliniella occidentalis (Pergande) es una de las plagas más importantes en el cultivo de limón mexicano en Michoacán, y su combate se basa en la utilización de insecticidas de amplio espectro. Sin embargo, hoy en día las poblaciones de trips son constantes en los huertos. Para comprender la influencia de los factores atmosféricos sobre la dinámica poblacional de la plaga en conjunto con sus enemigos naturales, se correlacionó durante cuatro años la densidad de la población de trips (Thysanoptera: Thripidae) y sus enemigos naturales con la temperatura (mínima, media y máxima) y la precipitación. Se encontró correlación positiva entre la densidad poblacional de *F. occidentalis* con la temperatura media y máxima, y una correlación positiva entre la densidad poblacional de los enemigos naturales con la precipitación y la temperatura mínima. Estos resultados resaltan el impacto de los factores ambientales en la regulación de las poblaciones de trips y los organismos benéficos. Con base en los resultados encontrados en esta investigación, se infiere que en el futuro habrá un aumento de las poblaciones de trips y una disminución de las poblaciones de insectos benéficos en la zona citrícola del Valle de Apatzingán. Es necesario implementar un cambio en el manejo fitosanitario actual, por lo que se propone un enfoque de manejo integrado que favoresca el papel de los enemigos naturales en el control biologico de plagas.

PALABRAS CLAVE: M Limón mexicano, plaga, trips, MIP (Manejo Integrado de Plagas), control de plagas

Introduction

The cultivation of Mexican lemon (*Citrus aurantifolia* Swingle) holds significant economic importance in Michoacán state, Mexico. 204,683 hectares are cultivated annually, producing 398,552 tons of fresh fruit and generating approximately 70,000 direct and indirect jobs (Servicio de Información Agroalimentaria y Pesquera, 2024). These jobs are distributed throughout the entire production chain, which includes production, processing, packaging, and export logistics, as well as complementary activities such as technical advisory services for the phytosanitary management of crops.

Among the main threats to lemon production in Michoacán is *F. occidentalis* (Pergande), a high-impact pest that affects the quality and yield of the crop. The primary strategy for controlling thrips has been the use of broad-spectrum chemical products, such as organophosphates, carbamates, and pyrethroids (Miranda-Salcedo *et al.,* 2019). However, the misuse of insecticides negatively affects the environment and consumer health (Mouden *et al.,* 2017; Desneux *et al.,* 2007). Currently, thrips populations are present year-round in citrus orchards, and farmers perceive that population densities are now higher than they were a decade ago (personal communication, M. Miranda Salcedo, Researcher, INIFAP-Experimental Field of the Apatzingán Valley).

A possible reason for the increased abundance of thrips populations is attributed to changes in environmental patterns observed in the region. According to Murray-Tortarolo (2020), Mexico, due to its geographical location, is one of the most vulnerable countries to climate change, and between 1951 and 2017 the national average temperature increased by 0.71 °C. Similarly, Sáenz-Romero *et al*. (2009), estimate that the average annual temperature in Michoacán will rise by 1.4°C by 2030, 2.2°C by 2060, and 3.4°C by 2090. Additionally, precipitation is expected to decrease, with projections indicating a 14.2 % reduction by 2030 in Michoacán under the worst-case scenario (Sáenz-Romero *et al*., 2009). This reduction will negatively impact agricultural production, which is expected to decline by 5 % to 30 % by 2080 (Parry *et al.,* 2004). Rising temperatures have been linked to increased natural pest populations, while also negatively affecting populations of beneficial insects. On the other hand, reduced rainfall may harm beneficial insect populations (Guerrero-Carrera *et al.,* 2020; Hódar *et al.,* 2012; Platero, 2015). Given this background, it is essential to understand how environmental factors, particularly temperature and rainfall, influence the population dynamics of *F. occidentalis* and its natural enemies in the citrus-growing region of the Apatzingán Valley, Michoacán, Mexico.

Material and Methods

Study area

The research was conducted from January 2019 to December 2022 in five Mexican lemon (*Citrus aurantifolia* Swingle) orchards located in the Apatzingán Valley, Michoacán, Mexico. The orchards were identified as A (19º02’40.6’’ N, 102º18’58.6’’ W), B (19°05’26” N, 102°24’52.2” W), C (19°00’40.8” N, 102°13’39.9” W), D (19º01’22.2’’ N, 102º16’24.4’’ W), and E (19°06’15.0” N, 102°12’50.5” W), and were classified according to their proximity to the meteorological station. These orchards are situated at an altitude of 350 to 360 masl and have an average size of 5 hectares. The distance between orchards ranges from 5 to 8 kilometers, ensuring sufficient separation of vegetation to reduce insect immigration and emigration. This short separation distance also aimed to homogenize the variability of environmental conditions present in the orchards. Additionally, collaborating farmers were asked to maintain their usual agronomic management practices, with the condition that any phytosanitary interventions be applied uniformly across the entire plot.

The agronomic management of the orchards mainly consisted of surface irrigation. During the dry season, the orchards were irrigated every 15 days, while no irrigation was applied during the rainy season. The main weeds present in the orchards were purple nutsedge (*Cyperus rotundus* L.), pigweed (*Amaranthus* spp.), and Johnsongrass (*Sorghum halepense* L. Pers.), among others. Periodic herbicide applications were carried out for weed control, as well as chemical insecticide applications approximately every two months for pest management.

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Additionally, botanical insecticides based on neem, garlic, and cinnamon were used, as well as chemical insecticides such as imidacloprid + lambda-cyhalothrin (200 g active ingredient (a.i.)/L + 140 g a.i./L) (Imiland®, Agricultura Nacional, Mexico) at a dose of 250 mL/ha, deltamethrin (25 g a.i./L) (Sidelt®, Agricultura Nacional, Mexico) at a dose of 0.5 L/ha, and thiamethoxam (750 g a.i./kg) (Actram 75 WDG®, Agricultura Nacional, Mexico) at a dose of 180 g/100 L. Herbicide applications included ammonium glufosinate (200 g a.i./L) (Agrofusinato Forte®, Agricultura Nacional, Mexico) at a dose of 1.5 L/200 L, and glyphosate (360 g a.i./L) (LaFAM®, Agricultura Nacional, Mexico) at a dose of 2 L/200 L.

Sampling of thrips and natural enemies

The monitoring of the thrips *Frankliniella occidentalis* and its natural enemies, including the green lacewing *Chrysoperla rufilabris* (Burmeister) (Neuroptera: Chrysopidae), the convergent lady beetle *Hippodamia convergens* (Guérin-Méneville) (Coleoptera: Coccinellidae), and the predatory mite *Amblyseius swirskii* (Athias-Henriot) (Acari: Phytoseiidae), was conducted as follows. Systematic grid sampling was performed with 20 sampling points (20 trees) as the sample size. Every 15 days, the population of thrips and the cumulative population of natural enemies were quantified. The sampling unit consisted of one branch from the middle part of each tree, ensuring visibility for insect quantification.

The collection of thrips and natural enemies was carried out by tapping tree shoots with a wooden stick over a blue board measuring 40 x 20 cm. The dislodged insects were collected and stored in jars containing 70 % alcohol for later taxonomic identification. The taxonomic identification was based on the methodologies of Soto-Rodríguez *et al*. (2017), for *F. occidentalis*, Cédola y Polack (2011), for *A. swirskii*, González (2006), for *H. convergens*, Valencia-Luna *et al*. (2006), and for *C. rufilabris*.

Climatic data

The data on minimum, average, and maximum temperature, as well as rainfall, were obtained weekly from the meteorological station of the National Water Commission (CONAGUA), located at the Faculty of Agricultural Sciences of the Universidad Michoacana de San Nicolás de Hidalgo (19°08’35.3’’ N, 102°37’11.0’’ W) (CONAGUA, 2024).

Statistical analysis

A correlational study was conducted based on observations and Pearson’s correlation analysis between the population densities of thrips and the cumulative population densities of natural enemies (the total population of each natural enemy from all samplings was normalized to 1, and the corresponding proportions for each sampling date were summed) these population densities were correlated with minimum, average, and maximum temperatures, as well as precipitation. The correlations were classified according to Evans (1996), as very weak for determination coefficients <0.2, weak for coefficients between 0.20-0.39, moderate for coefficients between 0.6 and 0.79, and very strong for coefficients >0.8. For cases where strong and very

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strong determination coefficients were found, a simple linear regression analysis was performed. The data were transformed to the square root (x+0.5) to meet the assumption of homogeneity of variances. The analyses were conducted using the SAS statistical software, version 9.4 ($p \leq 0.05$) (SAS Institute, 2013).

Results and discussion

Relationship between pest population fluctuations and environmental factors

When grouped by year, correlation data between the population density of the thrips *F. occidentalis* and the four measured environmental parameters (minimum, average, and maximum temperature, and precipitation) showed that, in 2019, only the relationship between thrips density and maximum temperature was statistically significant. However, the correlation was moderate ($P>F$ = 0.01, r = 0.68, R^2 = 0.47) (Table 1) (Figure 1).

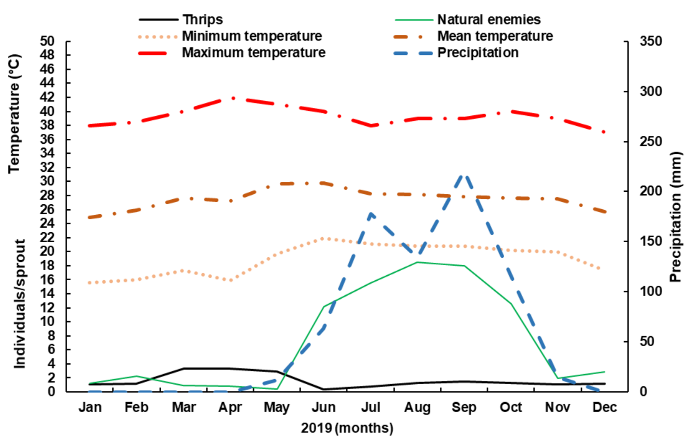

Figure 1. Population fluctuation of *Frankliniella occidentalis* and natural enemies against atmospheric factors (minimum temperature, mean temperature, maximum temperature, and rainfall) in 2019 in the Apatzingán Valley.

In 2020, statistically significant correlations were found in only two cases: between thrips density and average temperature, showing a weak positive correlation ($P>F$ = 0.04, r = 0.59, R^2 = 0.35), and between thrips density and maximum temperature, showing a moderate positive correlation ($P>F$ = 0.01, r = 0.7, R^2 = 0.49) (Table 1) (Figure 2).

In 2021, a similar pattern to the previous year was observed in the relationship between thrips density and average temperature, showing a strong correlation ($P>F$ = 0.0002, r = 0.87, R^2 = 0.72) (Table 1) (Figure 3) with the regression equation $Y = -17.78 + 0.69X$ (Table 2). A strong

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correlation was also found between thrips density and maximum temperature ($P>F$ = 0.0009, r = 0.82, R^2 = 0.68) (Table 1) (Figure 3) with the same regression equation $Y = -17.78 + 0.69X$ (Table 2).

Table 1. Results of simple linear correlation analysis between *Frankliniella occidentalis* population density with minimum, mean and maximum temperature, as well as precipitation, during 2019-2022, in the Apatzingán Valley, municipality of Parácuaro, Michoacán, Mexico.

Year	Correlation	df	r	R^2	F	$P>F$
2019	Thrips and Minimum tempeture	1	-0.41	0.17	2.07	0.18
	Thrips and Mean temperature	1	0.14	0.0098	0.10	0.75
	Thrips and Maximum temperature	1	0.68	0.47	9.02	0.01
	Thrips and Precipitation	1	-0.36	0.13	1.58	0.23
2020	Thrips and Minimum temperature	1	-0.07	0.005	0.05	0.82
	Thrips and Mean temperature	1	0.59	0.35	5.38	0.04
	Thrips and Maximum temperature	1	0.70	0.49	9.75	0.01
	Thrips and Precipitation	1	-0.04	0.19	2.42	0.15
2021	Thrips and Minimum temperature	1	0.29	0.08	0.96	0.34
	Thrips and Mean temperature	1	0.87	0.72	32.42	0.0002*
	Thrips and Maximum temperature	1	0.82	0.68	22	0.0009*
	Thrips and Precipitation	1	-0.21	0.04	0.47	0.50
2022	Trips and Minimum temperature	1	-0.04	0.0017	0.02	0.89
	Thrips and Mean temperature	1	0.54	0.30	4.31	0.06
	Thrips and Maximum temperature	1	0.90	0.82	45.60	<.0001*
	Thrips and Precipitation	1	-0.07	0.0052	0.05	0.82

*Variables with strong or very strong correlation (R^2>0.6) were subjected to simple linear regression analysis.

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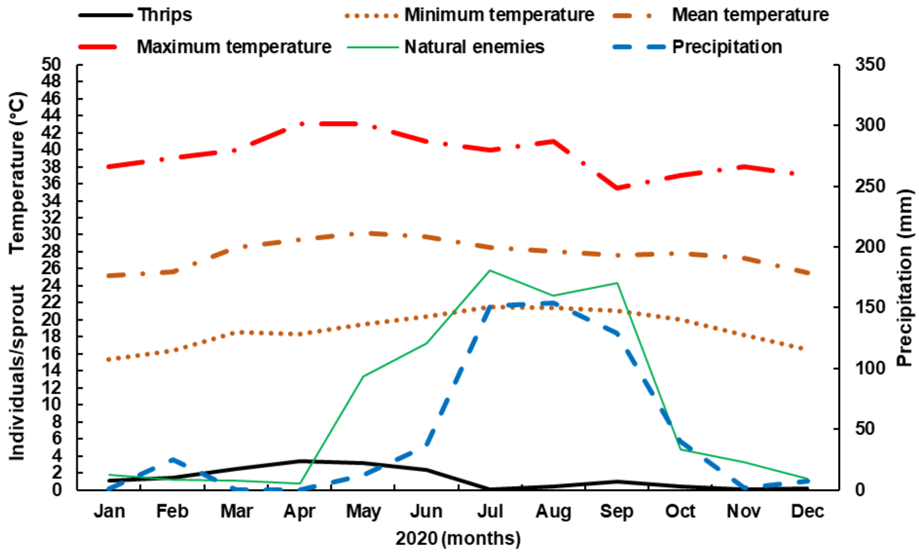

Figure 2. Population fluctuation of *Frankliniella occidentalis* and natural enemies against atmospheric factors (minimum temperature, mean temperature, maximum temperature and rainfall) in 2020 in the Apatzingán Valley.

Table 2. Equations of simple lineal regression of the population density of thrips about temperature.

Relation			**Linear equations**	**$Y = \beta_1 + \beta_0 X$**		
Year	**Dependent variable**	**Independent variable**	**β_1**	**Standard error**	**β_0**	**Standard error**
2021	Thrips	High temperature	-8.84	2.12	0.25	0.05
2021	Thrips	mean temperature	-17.78	3.31	0.69	0.12
2022	Thrips	Maximum temperature	-22.46	3.47	0.61	0.09

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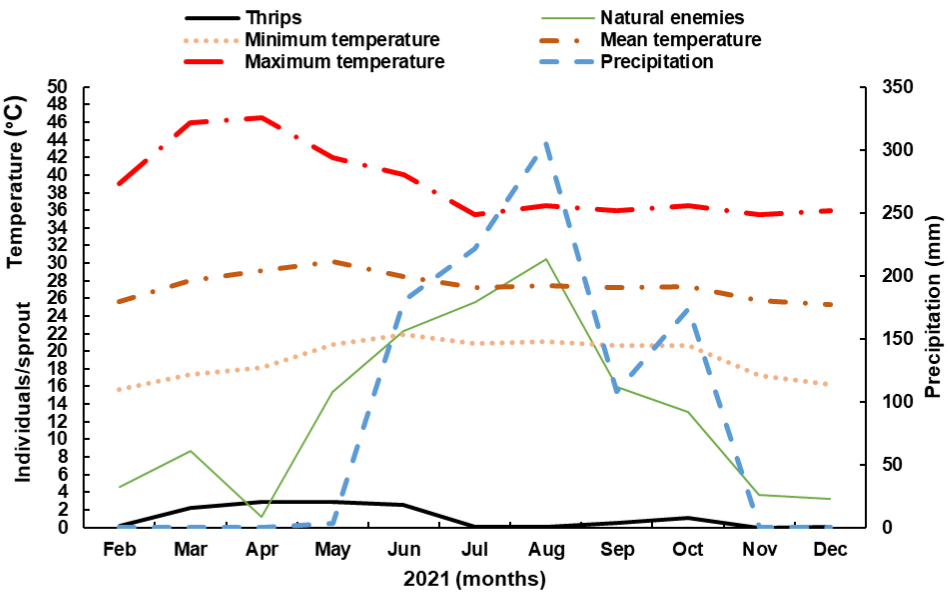

Figure 3. Population fluctuation of *Frankliniella occidentalis* and natural enemies against atmospheric factors (minimum temperature, mean temperature, maximum temperature and rainfall) in 2021 in the Apatzingán Valley.

In 2022, a statistically significant correlation was only found between thrips density and maximum temperature, which was positive and very strong ($P>F$ = 0.0001, r = 0.9, R^2 = 0.82) (Table 1) (Figure 4) with the linear regression *equation* $Y = -22.46 + 0.61X$ (Table 2).

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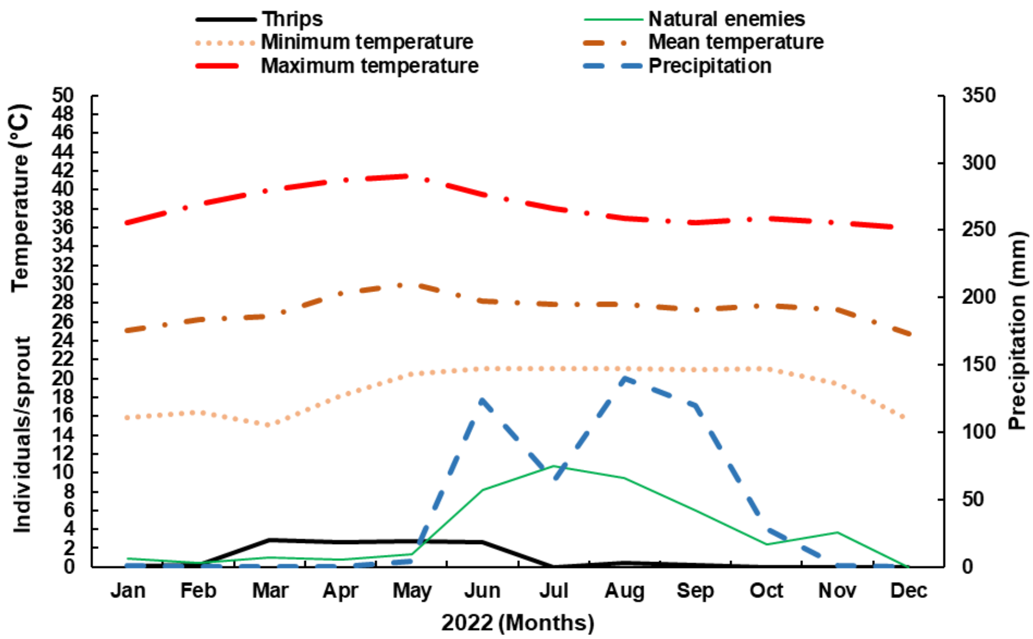

Figure 4. Population fluctuation of *Frankliniella occidentalis* and natural enemies against atmospheric factors (minimum temperature, mean temperature, maximum temperature and rainfall) in 2022 in the Apatzingán Valley.

Summarizing the details from the preceding paragraph, the population density of thrips was correlated with average and maximum temperatures but not with minimum temperature or precipitation. Temperature is a critical factor that influences the reproduction and development rates of thrips (Gao *et al.,* 2022). Specifically, higher temperatures are expected to accelerate the life cycle of *F. occidentalis*, leading to more generations per year and an increase in population densities (Contreras, 1998; Chingal *et al.,* 2016), as well as more severe damage, reaching up to 94 % of fruit damage (Murillo-Hernández *et al.,* 2022). On the other hand, Hardwick-Jones *et al.* (2010) reported that rainfall is correlated with relative humidity, which can also affect thrips survival rates (Mound, 1997; Mound and Teulon, 1995), but only in situations where humidity is very low. Low humidity can cause desiccation and higher mortality rates (Mound, 1997; Mound and Teulon, 1995). However, this study was conducted in citrus orchards with constant irrigation, and it is likely that conditions of low humidity that could affect the abundance of the thrips population never occurred.

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Relationship between natural enemy population fluctuations and environmental factors

Regarding the annual group correlation (2019-2021) between natural enemies and the four environmental parameters considered (minimum, average, and maximum temperature, and precipitation). In 2019, the group of natural enemies was correlated with minimum temperature ($P>F$ = 0.004, r = 0.75, R^2 = 0.56). A strong correlation was also found between natural enemies and precipitation ($P>F$ = 0.001, r = 0.93, R^2 = 0.88) with the linear regression equation $Y = -38.44 + 2.42X$ (Table 4). However, no statistically significant correlation was observed between natural enemies and average or maximum temperature (Table 3) (Figure 1).

Table 3. Results of the simple linear correlation analysis between the cumulative population of natural enemies with minimum, mean and maximum temperature, as well as with precipitation, during 2019-2022, in the Apatzingán Valley, municipality of Parácuaro, Michoacán, Mexico.

Year	**Correlation**	***df***	***r***	R^2	***F***	***P > F***
	Natural enemies and Minimum temperature	1	0.75	0.56	13.19	0.004*
	Natural enemies and Mean temperature	1	0.39	0.15	1.90	0.19
2019	Natural enemies and Maximum temperature	1	-0.18	0.03	0.34	0.57
	Natural enemies and Precipitation	1	0.93	0.88	73.83	<.0001*
	Natural enemies and Minimum temperature	1	0.84	0.72	25.76	0.0005*
	Natural enemies and Mean temperature	1	0.41	0.17	2.06	0.18
2020	Natural enemies and Maximum temperature	1	0.06	0.003	0.04	0.84
	Natural enemies and Precipitation	1	0.79	0.79	39.14	<.0001*
	Natural enemies and Minimum temperature	1	0.83	0.70	23.63	0.0007*
	Natural enemies and Mean temperature	1	0.32	0.10	1.21	0.29
2021	Natural enemies and Maximum temperature	1	-0.32	0.10	1.16	0.30
	Natural enemies and Precipitation	1	0.90	0.81	45.29	<.0001*
	Natural enemies and Minimum temperature	1	0.73	0.53	11.58	0.0067*
	Natural enemies and Mean temperature	1	0.32	0.10	1.16	0.30
2022	Natural enemies and Maximum temperature	1	-0.17	0.02	0.30	0.59
	Natural enemies and Precipitation	1	0.84	0.71	25.66	0.0005*

*Variables with strong or very strong correlation (R^2>0.6) were subjected to simple linear regression analysis.

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Table 4. Equations of simple linear regression population density of natural enemies about temperature and pluvial precipitation.

Relation			Linear equations $Y = \beta_1 + \beta_0 X$			
Year	Dependent variable	Independent variable	β_1	Standard error	β_0	Standard error
2019	Natural enemies	Pluvial precipitation	-12.42	12.01	12.19	1.18
2020	Natural enemies	Pluvial precipitation	2.89	1.77	0.14	0.02
2020	Natural enemies	Minimum temperature	-69.59	15.73	4.19	0.82
2021	Natural enemies	Minimum temperature	-53.62	13.70	3.5	0.72
2021	Natural enemies	Pluvial precipitation	6.06	1.56	0.07	0.01
2022	Natural enemies	Pluvial precipitation	1.38	0.77	0.05	0.01

In 2020, a strong statistically significant correlation was found between natural enemies and minimum temperature ($P>F$ = 0.0005, r = 0.84, R^2 = 0.71) with the linear regression equation $Y = -69.59 + 4.19X$ (Table 4). Similarly, a strong correlation was observed between natural enemies and precipitation ($P>F$ = 0.0005, r = 0.84, R^2 = 0.72) with the linear regression equation $Y = 2.98 + 0.14X$ (Table 4). No correlation was found between natural enemies and average or maximum temperature (Table 3) (Figure 2). In 2021, a very strong correlation was observed between natural enemies and minimum temperature ($P>F$ < 0.001, r = 0.83, R^2 = 0.79) with the linear regression equation $Y = -53.62 + 3.5X$ (Table 4). Likewise, a very strong correlation was also found between natural enemies and precipitation ($P>F$ < 0.0001, r = 0.9, R^2 = 0.81) with the linear regression equation $Y = 6.06 + 0.07X$ (Table 4). However, no statistical correlation was observed between natural enemies and average or maximum temperature (Table 3) (Figure 3). In 2022, a moderate correlation was observed between natural enemies and minimum temperature ($P>F$ = 0.0067, r = 0.73, R^2 = 0.53). Additionally, a strong correlation was observed between natural enemies and precipitation ($P>F$ = 0.005, r = 0.84, R^2 = 0.71) with the linear regression equation $Y = 1.38 + 0.05X$ (Table 4). No statistical correlation was found between natural enemies and average or maximum temperature (Table 3) (Figure 4).

The results from the previous paragraph collectively indicate that the population density of natural enemies was correlated with precipitation and minimum temperature, but not with average or maximum temperature. These results highlight the importance of environmental factors in regulating the populations of these beneficial organisms. Minimum temperatures are particularly critical because they determine the lower threshold for insect activity and development (Régnière *et al.,* 2012). In contrast, average temperatures affect the overall metabolic rates and growth cycles of these insects, with moderate temperatures generally promoting higher survival and reproductive success (Bale *et al.,* 2002). The lack of correlation with maximum temperature suggests that extreme heat may be detrimental to natural enemies (Jalali *et al.,* 2009; Ahmad *et al.,* 2015). The positive correlation with precipitation indicates that natural enemies benefit under

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conditions of high relative humidity. In the citrus-growing area of the Apatzingán Valley, various weed species begin to germinate with the first rains and, within 10-20 days, are fully developed and flowering. These plants provide food resources (exudates, nectar, and pollen) and shelter for beneficial insects. Additionally, their foliage helps retain moisture in the environment, creating a microclimate that favors the survival and proliferation of beneficial insects (Blanco & Leyva, 2007).

Since natural enemy populations increase with higher habitat humidity, practices to increase humidity could be implemented, such as mulching or maintaining cover crops that retain soil moisture. Promoting the conservation of beneficial insect populations through conservation biological control could also be effective (Blanco & Leyva, 2007; Vázquez *et al.,* 2008; José-Pablo, 2014).

Official records from the Mexican government indicate that temperature has been increasing in recent years, while precipitation has been decreasing (Figure 5a, 5b). Theoretically, due to the effects of climate change, both trends are expected to continue in the coming years in Mexico (NASA 2025; Murray-Tortarolo, 2020; Domínguez-Sarmiento & Jaramillo-Moreno, 2024). Obtained data suggest that if these trends continue, the population of thrips will increase while the population of natural enemies will decrease in the citrus-growing area of the Apatzingán Valley. This situation highlights the urgency of changing the current phytosanitary management strategy to an Integrated Pest Management (IPM) approach that strengthens the role of natural enemies for pest control. Since thrips populations increase with higher temperatures, the frequency and intensity of pest control measures will likely increase, especially during periods of higher temperatures.

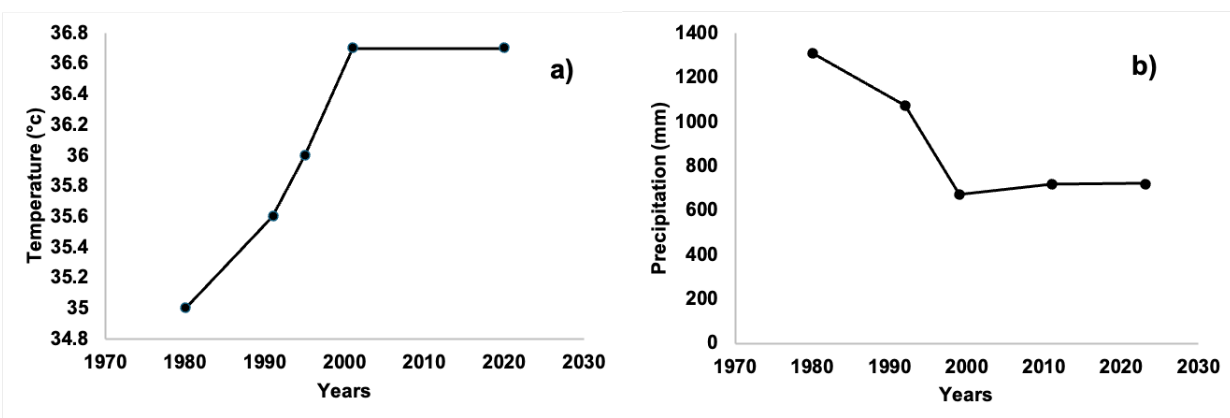

Figure 5. Maximum temperature (a) and rainfall (b) from 1980 - 2023 in the Apatzingán Valley, Michoacán, Mexico.

Conclusions

A correlation was found in some cases between the density of *F. occidentalis* and the average and maximum temperature, but no correlation was observed with precipitation. In contrast, natural enemies as a group were correlated with minimum and average temperature, as well as with precipitation. These results are useful for the implementation of integrated pest management (IPM) programs for thrips in the citrus-growing area of the Apatzingán Valley. Future research is recommended to collect on-site environmental data to understand better the behavior of *F. occidentalis* and its natural enemies with climatic factors.

Author Contributions

Conceptualization: PMS; Methodology development: PMS; Software management: PMS, GCJ; Experimental validation: PMS, GCJ, MHF, MSMA, AHJC, MFA; Data analysis: PMS, GCJ, MHF; Data management: PMS, MSMA; Manuscript writing and preparation: PMS, GCJ, MHF, AHJC, MFA; Drafting and review: PMS, GCJ, MHF; Project administration: MSMA.

All authors of this manuscript have read and approved the final published version.

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Conflict of Interest

The authors declare no conflict of interest.

Referencias

Ahmad-Ur-Rahman Saljoqi, N. A., Khan, J., Ehsan-ul-Haq, S., Rehman, Z. H., Saeed, H. G., Nadeem, M. S., & Zada, H. (2015). The impact of temperature on biological and life table parameters of *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae) fed on cabbage aphid, *Brevicoryne brassicae* (Linneaus). *Journal of Entomology and Zoology Studies*, 18, 265-288. https://www.entomoljournal.com/archives/2015/vol3issue2/PartE/63-402.pdf

Bale, J. S., Masters, G. J., Hodkinson, I. D., Awmack, C., Bezemer, T. M., Brown, V. K., Butterfield, J., Buse, A., Coulson, J. C., Farrar, J., Good, J. E. G., Harrington, R., Hartley, S., Jones, T. H., Lindroth, R. L., Press, M. C., Symrnioudis, I., Watt, A.D. & Whittaker, J. B. (2002). Herbivory in global climate change research: Direct effects of rising temperature on insect herbivores.

Revista Bio ciencias
ISSN 2007-3380

Global Change Biology, 8(1), 1-16. https://doi.org/10.1046/j.1365-2486.2002.00451.x
Blanco, Y., & Leyva, A. (2007). Las arvenses en el agroecosistema y sus beneficios agroecológicos como hospederas de enemigos naturales. *Cultivos tropicales*, *28*(2), 21-28. https://www.redalyc.org/pdf/1932/193217731003.pdf
Cédola, C., & Polack, A. (2011). Primer registro de Amblyseius swirskii (Acari: Phytoseiidae) en Argentina. *Revista de la Sociedad Entomológica Argentina*, 70(3-4), 375-378. https://www.redalyc.org/comocitar.oa?id=322028524024
Chingal, J. P. C., Belalcázar, G. C., & Ortega, J. A. S. (2016). Influencia de la temperatura sobre el ciclo de vida de la especie necrofaga Compsomyiops arequipensis Mello, 1968 (Diptera: calliphoridae). *Revista de la Asociación Colombiana de Ciencias Biológicas*, 1(28), 105. https://revistaaccb.org/r/index.php/accb/article/view/119
Comisión Nacional del Agua. (2024). Datos climatológicos de México por Municipio. https://smn.conagua.gob.mx/es/pronostico-del-tiempo-por-municipios
Contreras, J., Pedro, A., Sánchez, J. A., & Lacasa, A. (1998). Influencia de las temperaturas extremas en el desarrollo de *Frankliniella occidentalis* (Pergande)(Thysanoptera: Thripidae). *Boletin Sanidad Vegetal, Plagas*, *24*, 251-266. https://www.mapa.gob.es/ministerio/pags/Biblioteca/Revistas/pdf%5Fplagas%2FBSVP%2D24%2D02%2D251%2D266.pdf
Desneux, N., Decourtye, A., & Delpuech, J. M. (2007). The sublethal effects of pesticides on beneficial arthropods. *Annual Review of Entomology*, 52, 81-106. https://doi.org/10.1146/annurev.ento.52.110405.091440
Domínguez-Sarmiento, C. & A. Jaramillo-Moreno. (2024). [Boletín]. El Fortalecimiento del Sistema de Alerta Temprana Para Ciclones Tropicales (SIAT-CT) ante un Clima Cambiante. *Academia Mexicana de Impacto Ambiental*. 82,11-15. https://amia.org.mx/wp-content/uploads/2024/04/Boletin-Amia-82r.pdf
Evans, J. D. (1996). Straightforward statistics for the behavioral sciences. Thomson Brooks/Cole Publishing Co.
Gao, Y., Ding, N., Wang, D., Zhao, Y. J., Cui, J., Li, W. B., & Shi, S. S. (2022). Effect of temperature on the development and reproduction of Thrips flavus (Thysanoptera: Thripidae). *Agricultural and Forest Entomology*, *24*(3), 279-288. https://doi.org/10.1111/afe.12491
González, G. (2006). Los Coccinellidae de Chile. http://www.coccinellidae.cl
Guerrero-Carrera, J., Jaramillo-Villanueva, J. L., Mora-Rivera, J., Bustamante-González, Á., Vargas-López, S., & Chulim-Estrella, N. (2020). Impacto del cambio climático sobre la producción de café. *Tropical and Subtropical Agroecosystems*, *23*(71), 1-18. http://dx.doi.org/10.56369/tsaes.3288
Hardwick-Jones, R., Westra, S., & Sharma, A. (2010). Observed relationships between extreme sub-daily precipitation, surface temperature, and relative humidity. *Geophysical Research Letters*, *37*(22). https://doi.org/10.1029/2010GL045081
Hódar, J. A., Zamora, R., & Cayuela, L. (2012). Cambio climático y plagas: algo más que el clima. *Ecosistemas*, *21*(3), 73-78. https://doi.org/10.7818/ECOS.2012.21-3.09
Jalali, M. A., Tirry, L., & De Clercq, P. (2009). Effects of food and temperature on development, fecundity and life-table parameters of *Adalia bipunctata* (Coleoptera: Coccinellidae). *Journal of Applied Entomology*, *133*(8), 615-625. https://doi.org/10.1111/j.1439-0418.2009.01408.x
José-Pablo, R. (2014). La Crisopa *Ceraeochrysa valida:* recurso local con potencial de depredación contra el psílido asiático de los cítricos [Tesis de Maestría, Colegio de Postgraduados].

http://colposdigital.colpos.mx:8080/xmlui/handle/10521/2895
Miranda-Salcedo, M.A., E. Loera-Alvarado & E. Cortez-Mondaca. (2019). Interacción de trips (Thysanoptera: Thripidae) y sus enemigos naturales en limón mexicano, en Michoacán. (Memoria de congreso). Memoria XLII Congreso Nacional de Control Biológico, Veracruz, Ver. 71-75 pp. https://drive.google.com/file/d/1pXX8OmiN-okiq4TzPd-IMGErvO6j5jjA/view
Mouden, S., Sarmiento, K. F., Klinkhamer, P. G., & Leiss, K. A. (2017). Integrated pest management in western flower thrips: past, present and future. *Pest management science*, *73*(5), 813-822. https://doi.org/10.1002/ps.4531
Mound, L.A. (1997). Biological Diversity. In: Thrips as Crop Pests, edited by T. Lewis. CAB International, Wallingford, UK. 197-215.
Mound, L.A., &Teulon D.A. (1995). Thysanoptera as phytophagous opportunists. In Thrips biology and management. Boston, MA: Springer US. 3-19.
Murillo-Hernández, J. E., Illescas-Riquelme, C. P., López-Lima, D., & Manzanilla-Ramírez, M. Á. (2022). Incidencia y Daños de Scirtothrips dorsalis en Plantaciones de Limón Mexicano en Colima, México. *Southwestern Entomologist*, 47(1), 211-214. https://doi.org/10.3958/059.047.0120
Murray-Tortarolo, G. N. (2021). Seven decades of climate change across Mexico. Atmósfera, 34(2), 217-226. https://doi.org/10.20937/atm.52803
National Aeronautics and Space Administration [NASA]. (2025). Global Temperature. En línea: (https://climate.nasa.gov/vital-signs/global-temperature/?intent=121)
Parry, M. L., Rosenzweig, C., Iglesis, A., Livermore, M. & Fisher, G. (2004). Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environmental Change*, 14 (1), 53-67. https://doi.org/10.1016/j.gloenvcha.2003.10.008
Platero, G. G. R. (2015). Cambio Climático y Plagas Agrícolas. (Conference Paper). Foro Nacional de Cambio Climático. Managua, Nicaragua. https://www.researchgate.net/profile/Gonzalo-Galileo-Rivas-Platero/publication/278410790_Cambio_climatico_y_plagas_agricolas/links/55809f4f08ae607ddc322719/Cambio-climatico-y-plagas-agricolas.pdf.
Régnière, J., Powell, J., Bentz, B., & Nealis, V. (2012). Effects of temperature on development, survival and reproduction of insects: Experimental design, data analysis and modeling. *Journal of Insect Physiology*, 58(5), 634-647. https://doi.org/10.1016/j.jinsphys.2012.01.010.
Sáenz-Romero, C., Rehfeldt, G. E., Crookston, N. L., Duval, P. & Beaulieu, J. (2009). Estimaciones de cambio climático para Michoacán: Implicaciones para el sector agropecuario y forestal y para la conservación de la Mariposa Monarca. Consejo Estatal de Ciencia y Tecnologıa de Michoacán, México. https://www.fs.usda.gov/rm/pubs_other/rmrs_2009_saenz_romero_c001.pdf
SAS Institute. 2013. The Complete Guide to the SAS Output Delivery System: Version 9.4 SAS Institute Inc., Cary.
SIAP (Servicio de Información Agroalimentaria y Pesquera) (2024). Avances de Siembras y Cosechas. En línea: https://nube.siap.gob.mx/avance_agricola/.
Soto-Rodríguez, G. A., Rodríguez-Arrieta, J. A., González Muñoz, C., Cambero-Campos, J., & Retana-Salazar, A. P. (2017). Clave para la identificación de géneros de Thrips (Insecta: Thysanoptera) comúnmente asociados a plantas ornamentales en Centroamérica. *Acta zoológica mexicana*, *33*(3), 454-463. https://doi.org/10.21829/azm.2017.3331146
Valencia-Luna, L. A., Romero-Nápoles, J., Valdez-Carrasco, J., Carrillo-Sánchez, J. L., & López-

Revista Bio ciencias
ISSN 2007-3380

Martínez, V. (2006). Taxonomía y registros de Chrysopidae (Insecta: Neuroptera) en el estado de Morelos, México. *Acta zoológica mexicana*, *22*(1), 17-61. https://doi.org/10.21829/azm.2006.2211959

Vázquez, L. L., Alfonso, J., Matienzo, Y., & Veitía, M. (2008). Conservación y manejo de enemigos naturales de insectos fitófagos en los sistemas agrícolas de Cuba. (pp. 198-198). Ed. CIDISAV. https://www.researchgate.net/profile/Luis-Vazquez-50/publication/268981130_Conservacion_y_manejo_de_enemigos_naturales_de_insectos_fitofagos_en_los_sistemas_agricolas_de_Cuba/links/566c692208aea0892c4fc59d/Conservacion-y-manejo-de-enemigos-naturales-de-insectos-fitofagos-en-los-sistemas-agricolas-de-Cuba.pdf