Short Note [Nota Corta]

PLANT PARASITIC NEMATODES ASSOCIATED WITH TREE TOMATO (*Solanum betaceum* Cav.) IN TLACOLULAN AND XALAPA, VERACRUZ, MEXICO†

[NEMATODOS FITOPARÁSITOS ASOCIADOS CON TOMATE DE ARBOL (*Solanum betaceum* Cav.) EN TLACOLULAN Y XALAPA, VERACRUZ, MÉXICO]

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SUMMARY

Background: Tree tomato (*Solanum betaceum* Cav.) is a plant introduced to Mexico since colonial times, currently it is found as a crop in backyard orchards in the central mountainous region of Veracruz. Due to its nutraceutical properties, its cultivation is gaining importance worldwide and spreading. However, since there are no established formal crops in Mexico, there are no studies on the pests that may affect the development of this plant. **Objective:** To identify the plant-parasitic nematodes associated with the rhizospheric soil and root, as well as the determine their abundance in tree tomato plants, located in the Tlacolulan and Xalapa municipalities, in Veracruz state. **Methodology:** The nematodes were extracted from the soil and roots, fixed, clarified, mounted for identification at the genus level, and quantified. **Results:** 704 specimens belonging to 14 genera were identified: *Criconema, Criconemoides, Filenchus, Fraglenchus, Gracilacus, Helicotylenchus, Malenchus, Meloidogyne, Ogma, Paratylenchus, Pratylenchus, Pratylenchoides*, *Sakia,* and *Thada*. The most abundant nematodes were *Helicotylenchus* and *Meloidogyne.* **Implications:** Since in five samples we found *Meloidogyne* individuals, a diagnosis must be made prior to the establishment of new crops to avoid the increase in populations that can affect the performance of the plants. **Conclusion:** *Criconema, Filenchus, Fraglenchus, Malenchus, Ogma, Pratylenchoides, Sakia,* and *Thada* are recorded for the first time associated with this plant.

Key words*: Helicotylenchus; Meloidogyne;* Criconematidae; Tylenchidae; soil pests.

RESUMEN

Antecedentes: El tomate de árbol (*Solanum betaceum* Cav.) es una planta introducida a México desde la época colonial, actualmente se encuentra como cultivo en huertas de traspatio en la región montañosa central de Veracruz. Debido a sus propiedades nutracéuticas, su cultivo está ganando importancia en el mundo y se está extendiendo. Sin embargo, dado que en México no existen cultivos formales establecidos, no hay información sobre las plagas que pueden afectar el desarrollo de esta planta. **Objetivo:** Identificar los nematodos fitoparásitos asociados al suelo rizosférico y raíz, así como determinar su abundancia en plantas de tomate de árbol, ubicadas en los municipios de Tlacolulan y Xalapa, en el estado de Veracruz. **Metodología:** Los nematodos fueron extraídos del suelo y raíces, fijados, aclarados, montados para su identificación a nivel de género y cuantificados. **Resultados:** Se identificaron 704 ejemplares pertenecientes a 14 géneros: *Criconema*, *Criconemoides*, *Filenchus*, *Fraglenchus*, *Gracilacus*, *Helicotylenchus*, *Malenchus*, *Meloidogyne*, *Ogma*, *Paratylenchus*, *Pratylenchus, Pratylenchoides*, *Sakia* y *Thada*. Los nematodos más abundantes fueron *Helicotylenchus* y *Meloidogyne*. **Implicaciones:** Dado que en cinco muestras encontramos individuos de *Meloidogyne*, se debe realizar un diagnóstico previo al establecimiento de nuevos cultivos para evitar el aumento de poblaciones que pueden afectar el rendimiento de las plantas. **Conclusión:** *Criconema*, *Filenchus*, *Fraglenchus*, *Malenchus*, *Ogma*, *Pratylenchoides, Sakia* y *Thada* se registran por primera vez asociados a esta planta.

Palabras clave*: Helicotylenchus; Meloidogyne;* Criconematidae; Tylenchidae; plagas del suelo.

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INTRODUCTION

Solanum betaceum Cav. (Solanaceae) is native to southern Bolivia and northeastern Argentina, where it is found at altitudes between 1,100 and 2,300 meters above sea level (masl) (Bohs, 1994). During colonial times, the Spanish and Portuguese took it to various countries, and now, can be found plantations in various parts of the world (Lamas *et al*., 2022). Due to this distribution, it is known by various names such as mountain tomato, tamarillo, chilto, eggplant, and the main producing and exporting countries of this fruit are New Zealand, Portugal, Colombia, Ecuador, and Peru (Prohens *et al*., 1996; Ramírez and Kallarackal, 2019). This species has gained importance due to its nutraceutical properties, including the amount of polyphenols, flavonoids, carotenoids, anthocyanins, and vitamin C (Diep *et al*., 2020; Isla *et al*., 2022; Viera *et al*., 2022). Although it is not known when it was introduced to Mexico, there are records of specimens collected in the states of Chiapas (1945-1965), Guanajuato (1897), Jalisco (1886) and Veracruz (1976-1981) growing between 1,000 and 1,300 masl (Bohs, 1994). In the central region of Veracruz, the tree tomato has remained as a backyard crop and in the wild as part of the useful plants that grow under oak and cloud forests or in shaded coffee plantations. There are also small plantations, which have acquired commercial importance due to local and regional consumption and production prospects increasing (Villegas-Ruiz *et al*., 2013; Feicán-Mejía *et al*., 2016). In Ecuador and Colombia, where it is cultivated extensively and intensively, many aspects of tree tomato have been studied (Prohens and Nuez, 2001; Acosta-Quezada *et al*., 2011), including several pathogens (nematodes, fungi, bacteria, and viruses) that limit their production (Jaramillo *et al*., 2012; López-Cardona and Castaño-Zapata, 2013; Ramírez-Gil *et al*., 2017). In the Ecuador highlands, more than 10 genera of plant-parasitic nematodes associated with *S. betaceum* have been recorded, *Meloidogyne*, *Nacobbus* and *Pratylenchus* are the most frequent, causing in some cases losses greater than 90% and halving the useful life of the crop (Ramírez *et al*., 2015; Ubidia and Soria, 2017). Infected plants present symptoms such as nutrient deficiency, which is why on many occasions, the nematodes go unnoticed and proper management is not carried out (Wheeler *et al*., 2019). In Mexico, because *S. betaceum* is not intensively cultivated, there are no studies on its phytopathogens. However, considering the growing importance of this crop, it is necessary to study the possible pest organisms present in the areas where this plant grows, including plant-parasitic nematodes. In the present work, the genera of plant-parasitic nematodes associated with roots and rhizospheric soil of *S. betaceum* were identified and their abundance was determined.

MATERIALS AND METHODS

Soil and root samples were collected in October 2020 in the Tlacolulan and Xalapa municipalities, both in the Veracruz state, Mexico (Table 1). The sampled plants were found in backyard orchards or in the wild in the understory of the original vegetation (oak forest and cloud forest). At each sampling site, approximately 250 g of rhizospheric soil and 20 g of root tissue were taken. The samples were placed in plastic bags labeled with the location data of each plant and then taken to the laboratory. In total, 8 samples were taken in Tlacolulan and two in Xalapa.

For the extraction of ectoparasitic nematodes, 100 cm^3 of soil from each sample was processed using the sieving-centrifugation technique (van Bezooijen, 2006). For the extraction of endoparasitic nematodes, 10 g of root tissue from each sample was processed with the maceration, sieving, and centrifuging technique (van Bezooijen, 2006). The nematodes obtained from each sample were fixed with 4% boiling formalin and clarified by the Seinhorst method (1962). Subsequently, the specimens were placed in a Sedgwick-Rafter counting chamber and observed under a light microscope at 100X. The specimens with a stylet were mounted in a paraffin ring (van Bezooijen, 2006) on glass slides to observe them in the light microscope at 400 and 1000X and carry out the identification at the genus level based on morphological characters, such as stylet, esophagus, labial region, cuticle, reproductive organs and posterior region according to the taxonomic keys of the Tylenchida order (Siddiqi, 2000). Subsequently, the specimens were quantified, and the abundance of each genus was determined.

RESULTS AND DISCUSSION

Plant parasitic nematodes obtained (704 specimens) from rhizospheric soil and tree tomato roots correspond to 14 genera: *Criconema, Criconemoides, Filenchus, Fraglenchus, Gracilacus, Helicotylenchus, Malenchus, Meloidogyne, Ogma, Paratylenchus, Pratylenchus, Pratylenchoides*, *Sakia,* and *Thada* (Table 1, Figure 1). From the total number of nematodes obtained, five were identified only at the family level (two Tylenchidae specimens) and subfamily (one Hoplolaiminae specimen and two Pratylenchinae specimens).

The nematodes associated with *S. betaceum* in this study coincide with those registered in the producing areas of Colombia and Ecuador where *Criconemoides, Helicotylenchus, Meloidogyne, Paratylenchus* and *Pratylenchus* are present (Lozada *et al*., 2002; Ubidia & Soria, 2017). In addition, they have registered *Heterodera, Nacobbus, Radopholus, Rotylenchus,*

Table 1. Geographical data of collecting sites in tree tomato plants from Tlacolulan and Xalapa municipalities (Veracruz, Mexico) and diagnosed genera.

Municipality	Sample	Location	Altitude masl	Cultivated/wild	Genera‡
Tlacolulan	T1	19°39'51"N 97°00'07"W	1764	Backyard crop	*Criconemoides, Filenchus, Gracilacus, Helicotylenchus, Malenchus, Meloidogyne, Pratylenchus*
	T2	19°39'53"N 97°00'21"W	1776	Wild	*Helicotylenchus, Thada*
	T3	19°40'3.69"N 97°00'12"W	1776	Backyard crop	*Meloidogyne, Thada*, Tylenchidae
	T4	19°40'19"N 97°00'14"W	1840	Wild	*Helicotylenchus, Fraglenchus, Malenchus, Pratylenchoides*
	T5	19°39'53"N 97°00'22"W	1777	Wild	*Helicotylenchus*
	T6	19°40'02"N 97°00'12"W	1780	Backyard crop	*Criconemoides, Helicotylenchus, Meloidogyne, Ogma, Pratylenchus,* Pratylenchinae
	T7	19°39'53"N 97°00'15"W	1772	Wild	*Helicotylenchus, Ogma*
	T8	19°40'3.74"N 97°00'18"W	1846	Backyard crop	*Criconema, Criconemoides, Helicotylenchus,* Hoplolaiminae, *Meloidogyne, Ogma, Paratylenchus,* Tylenchidae
Xalapa	X1	19°34'1.36"N 96°55'00"W	1402	Backyard crop	*Criconemoides*
	X2	19°34'08"N 96°54'27"W	1381	Backyard crop	*Malenchus, Meloidogyne, Sakia*

‡Based on morphological characters according to the taxonomic keys of the Tylenchida order (Siddiqi, 2000).

Tylenchus and *Trichodorus* (Ramírez *et al*., 2015; Mosquera-Espinosa, 2016). Likewise, in Kenya, *Belonolaimus*, *Hemicycliophora*, *Longidorus*, *Paralongidorus*, *Paratrichodorus* and *Xiphinema* have been recorded associated with this plant (Waswa *et al*., 2020). The difference in the genera registered in South America and those found in the present work may be due to the different environmental conditions in which the plants develop since in the areas of origin the studies were carried out on commercial crops and agricultural practices significantly influence the rhizosphere nematofauna (Guesmi-Mzoughi *et al*., 2022). On the other hand, in the present study the genera *Criconema*, *Filenchus*, *Fraglenchus*, *Gracilacus*, *Malenchus*, *Ogma*, *Pratylenchoides*, *Sakia*, and *Thada* are reported on *S. betaceum* for the first time. *Criconema* species parasitize 28 families of plants and have a preference for woody plants. It is suggested that crops susceptible to these nematode species should be grown away from forest areas (Rathore, 2019). It is likely that the presence of *Criconema* on *S. betaceum* is related to the presence of nearby trees. The species of the genus *Filenchus* are characterized by feeding on the epidermal cells of plant roots and fungal hyphae and may even feed on phytopathogenic fungi (Yeates *et al*., 1993; Okada *et al*., 2005; Munawar *et al*., 2022). However, there are no records of significant damage to crops, it is possible that they are found in the rhizosphere of the tree tomato feeding on fungi. The genus *Gracilacus* is common in undisturbed and cultivated soils, nonetheless, it is not considered of economic importance (Castillo *et al*., 1989). According to our bibliographical review, no significant damage to crops was reported. *Malenchus* species have a cosmopolitan distribution, their feeding habit is not well defined, but they are commonly found in association with decaying organic matter in the rhizosphere (Pedram *et al*., 2018), and no significant damage to crops was reported. *Ogma* species are commonly associated with trees such as *Pinus* spp. In particular, *O. rhombosquamatum* causes thickening of root cortical cells, leading to necrosis in the olive trees epidermis, all the same, it is not considered of economic importance (Vovlas and Inserra, 1981). *Pratylenchoides* species are migratory endoparasites on several crops (Ghaderi and Karegar, 2014). These nematodes have been found to affect the roots of *Solanum lycopersicum* and *Perilla frutescens* (Li *et al*., 2020; Kang *et al*., 2023). Tomato trees may be susceptible to *Pratylenchoides*; yet, pathogenicity studies are needed to determine its potential as a pest. Regarding the genera *Fraglenchus*, *Sakia* and *Thada*, they have been found in the rhizosphere of several plants, but there is no definitive information about their feeding habits (Siddiqi, 2000) and, according to our bibliographic review, they are not considered agricultural pests.

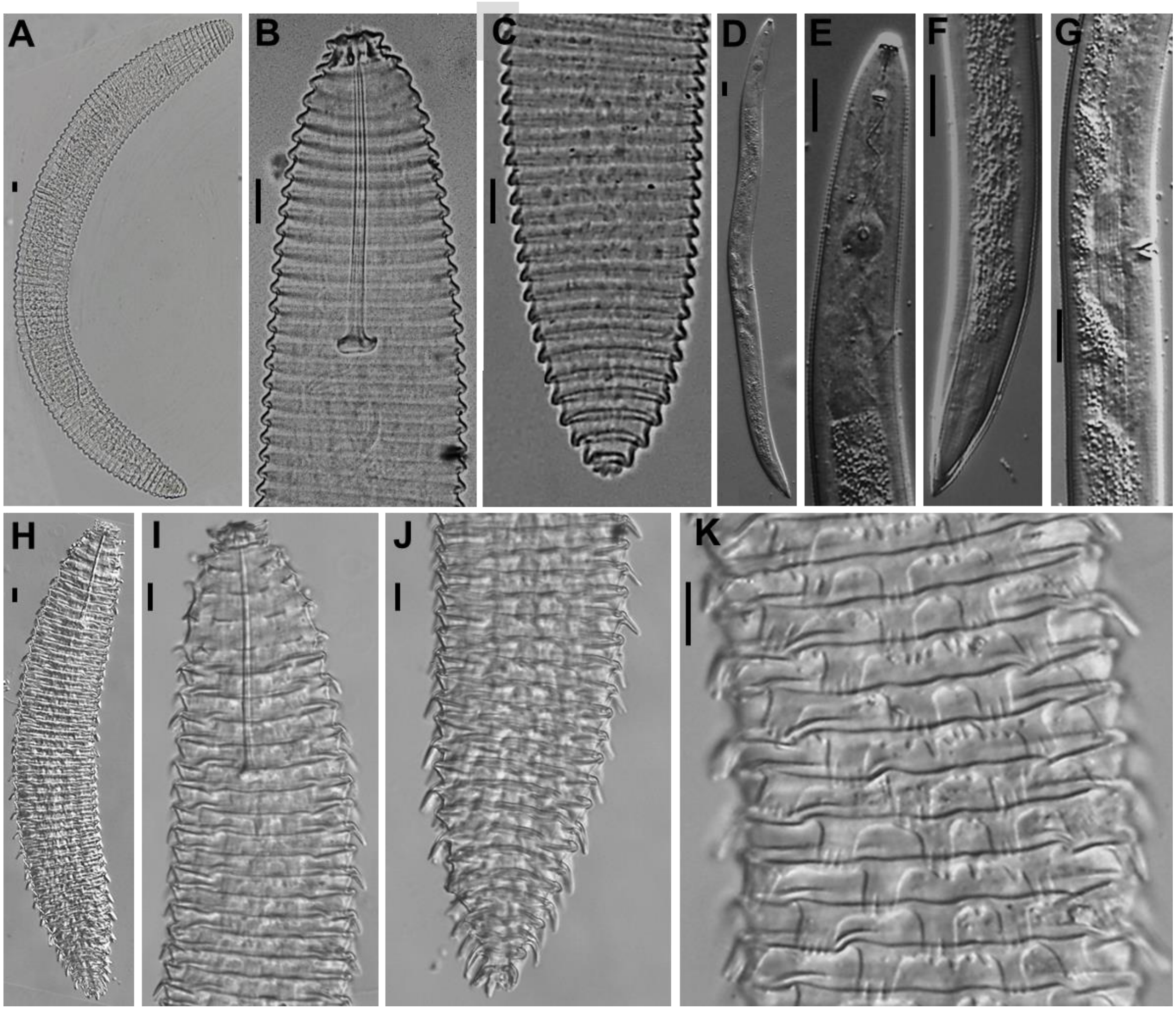

Figure 1. *Criconemoides* sp. female: A) entire body, B) body anterior region, C) posterior region. *Pratylenchoides* sp. female: D) entire body, E) body anterior region, F) posterior region, G) lateral field with six incisures. *Ogma* sp. female: H) entire body, I) anterior region, J) posterior region, K) body annules with finger-like projections (Scale bars = 10 µm). All photographs of the nematodes are original and were taken by the authors.

The highest abundance in rhizospheric soil was found in sample 5 from Tlacolulan, with 200 specimens per 100 cm^3 $soil^{-1}$, all the genus *Helicotylenchus*, followed by sample 6 from the same locality with 97 specimens per 100 cm^3 $soil^{-1}$ of which 80 were *Helicotylenchus*, 16 *Criconemoides* and one *Meloidogyne* specimen. Likewise, sample 1 of Tlacolulan presented the highest *Meloidogyne* abundance in soil, with 30 specimens, followed by *Criconemoides* and *Filenchus* with 24 and 14 specimens respectively (Table 2). The highest abundance in the roots was found in sample 2 from Xalapa with 116 specimens per 10 g of which 113 correspond to *Meloidogyne* and 3 to *Malenchus*. Likewise, samples 5 and 6 of Tlacolulan presented a density of 31 and 46 nematodes per 10 g $root^{-1}$ where the most abundant genus was *Helicotylenchus,* coinciding with the soil samples from the same sites (Table 3).

The most abundant genus in this work was *Helicotylenchus*, which contrasts with the tree tomato-producing areas of Colombia (Mosquera-Espinosa, 2016), Ecuador (Ubidia and Soria, 2017), Kenya (Juma *et al*., 2020; Waswa *et al*., 2020), and New Zealand (Knight, 2001) where the highest abundance corresponds to the *Meloidogyne* genus. This could be due to the monoculture effect, which provides favorable conditions for *Meloidogyne* reproduction such as low biological diversity in the soil. Likewise, some of the most affected plantations were established in fields where vegetables, coffee, plantain, lulo and other plants highly susceptible to *Meloidogyne* were previously grown (Lozada *et al*., 2002; García *et al*., 2004; Mosquera-Espinosa, 2016). In contrast, the plants studied in the present work were found in backyard orchards or growing wild, which allows the regulation of plant-parasitic nematode abundance, due to the greater biological diversity in the soil (Topalovic *et al*., 2020).

Although *Meloidogyne* J2 juveniles were found in five of the samples studied, no significant root damage was observed, even in sample 2 from Xalapa where a high infestation level was recorded. It is necessary to carry out the *Meloidogyne* species determination in the plants and their pathogenicity. On the other hand, to date, there are no studies to calculate the economic threshold regarding the nematode infestation in *S. betaceum* (Lozada *et al*., 2002). In general, for *Meloidogyne*, between 1 and 5 individuals per gram of soil are considered to cause losses in various Solanaceae species (Firoza and Maqbool, 1995; Evlice *et al*., 2021; Talavera-Rubia *et al*., 2022). According to these data, all the samples where *Meloidogyne* individuals were detected could be affected. However, it is necessary to carry out studies to determine the tolerance to the different plant-parasitic nematodes genera in *S. betaceum* and to establish an economic threshold for this plant.

Table 2. Plant parasitic nematode abundance in 100 cm^3 of *Solanum betaceum* rhizospheric soil in the Tlacolulan (T) and Xalapa (X) municipalities, Veracruz, Mexico.

Family/Genera	**Site**									
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**X1**	**X2**
Criconemoides	24					16		7	1	
Filenchus	14									
Gracilacus	1									
Helicotylenchus	3	2		52	200	80	6	3		
Malenchus										1
Meloidogyne	30					1		6		
Paratylenchus								5		
Sakia										1
Thada		2	1							
Tylenchidae			1							
Total	**71**	**4**	**2**	**52**	**200**	**97**	**6**	**21**	**1**	**2**

Table 3. Plant parasitic nematode abundance in 10 g root^{-1} of *Solanum betaceum* in the Tlacolulan (T) and Xalapa (X) municipalities, Veracruz, Mexico.

Family/Genera	**Site**									
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**X1**	**X2**
Criconema								1		
Criconemoides						1		2		
Fraglenchus				2						
Helicotylenchus	1				31	40		8		
Hoplolaiminae								1		
Malenchus	1			6						3
Meloidogyne			2					1		113
Ogma						2	1	1		
Paratylenchus								15		
Pratylenchus	1					1				
Pratylenchinae						2				
Pratylenchoides				11						
Tylenchidae								1		
Total	**3**	**0**	**2**	**19**	**31**	**46**	**1**	**30**	**0**	**116**

CONCLUSIONS

The diagnosis of plant-parasitic nematodes is difficult because it is not possible to perform visual evaluations in the aerial parts of the plants since the damage is caused in the roots. Making a proper diagnosis before establishing new crops or undertaking management actions is important. In the municipalities of Tlacolulan and Xalapa, Veracruz, Mexico, a diversity of plant-parasitic nematodes was found associated with the rhizospheric soil and the roots of *S. betaceum*. *Criconema, Filenchus, Fraglenchus, Malenchus, Ogma, Pratylenchoides, Sakia,* and *Thada* are recorded for the first time associated with *S. betaceum*. In most of the samples, the nematode abundance was low to affect plant development. However, we recommend carrying out a diagnosis prior to the establishment of crops to prevent the increase in populations that could affect plant yield.

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Compliance with ethical standards. The authors confirm that this investigation was conducted under the current ethical procedures. No humans or animals were used in the studies of this article.

Data availability. Data is available with the corresponding author upon request.

Author contribution statement (CRediT). G. Carrión: Conceptualization, Writing, Methodology, Supervision. **L. Velasco-Rodríguez**: Writing, Sample acquisition, Methodology. **D. López-Lima**: Conceptualization, Investigation, Writing, Validation.

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