Diversity and regional distribution of plant-parasitic nematodes associated with sugarcane (*Saccharum officinarum* L.) in Veracruz, Mexico †

[Diversidad y distribución regional de nematodos fitoparásitos asociados a caña de azúcar (*Saccharum officinarum* L.) en Veracruz, México]

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SUMMARY

Background: Sugarcane is one of the most important crops in Mexico due to its extensive cultivation, the production of high-value commercial products, and its significant economic impact. Among the main pests affecting this agroecosystem are plant-parasitic nematodes. However, despite their potential to reduce crop productivity, these organisms have received limited attention in Mexico**. Objective:** To determine the diversity, distribution and abundance of phytoparasitic nematodes associated with *Saccharum officinarum* L. in the state of Veracruz. **Methodology:** A total of 50 composite soil and roots samples were collected from the supply areas of five sugar mills located across the four sugarcane growing regions of the state during the 2023 tillering season. Nematodes were identified to genus level, quantified, and their diversity and abundance were analyzed in relation to soil texture and organic matter content. **Results**: Nine genera of plant-parasitic nematodes associated with sugarcane were identified: *Aphelenchus*, *Criconemoides*, *Helicotylenchus*, *Hoplolaimus*, *Pratylenchus*, *Psilenchus*, *Rotylenchus*, *Trichodorus*, and *Trophurus*. *Pratylenchus* and *Helicotylenchus* were the most abundant genera and were detected in 100% of the soil and root samples. The highest average population densities of *Pratylenchus* were recorded in the supply areas of El Modelo and Mahuixtlán mills, with 1,430 and 1,247 individuals per 50 g of root, respectively. The nematode genera identified were primarily associated with clay and loam textures soil textures. No relationship was observed between soil organic matter content and the presence of specific genera. **Implications:** This study is the first diagnosis of phytoparasitic nematodes in the main sugarcane-growing regions in Veracruz. Further research is required to assess the damage potential of each species and establish economic thresholds based on agronomic and environmental condictions in each production region. **Conclusion:** The presence of plant-parasitic nematodes in the sugarcane rhizosphere was confirmed. The genus *Pratylenchus* was predominant and may be responsible for yield losses in the crop.
Key words: *Pratylenchus*; *Helicotylenchus*; soil pests; diversity; abundance.

† *Submitted May 28, 2025 – Accepted March 5, 2026.* http://doi.org/10.56369/tsaes.6358

ISSN: 1870-0462.
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RESUMEN

Antecedentes: En México, la caña de azúcar es uno de los cultivos más importantes debido a su amplia distribución territorial, la obtención de insumos de alto valor comercial y su significativo impacto económico. Entre las principales plagas que afectan este agroecosistema se encuentran los nematodos fitoparásitos; sin embargo, en el país estos organismos han recibido poca atención, a pesar del impacto que pueden tener en la productividad del cultivo. **Objetivo**: Determinar la diversidad, distribución y abundancia de nematodos fitoparásitos asociados a *Saccharum officinarum* L, en el estado de Veracruz. **Metodología**: Se recolectaron un total de 50 muestras compuestas de suelo y raíces de las zonas de abastecimiento de cinco ingenios azucareros, distribuidos en las cuatro regiones cañeras del estado durante la etapa de macollamiento en 2023. Los nematodos se identificaron a género, se cuantificaron y se determinó su diversidad, abundancia y relación con la textura y el porcentaje de materia orgánica del suelo. **Resultados**: Se identificaron nueve géneros de nematodos fitoparásitos asociados al cultivo de caña de azúcar: *Aphelenchus*, *Criconemoides*, *Helicotylenchus*, *Hoplolaimus*, *Pratylenchus*, *Psilenchus*, *Rotylenchus*, *Trichodorus* y *Trophurus*. *Pratylenchus* y *Helicotylenchus* fueron los géneros más abundantes y estuvieron presentes en el 100% de las muestras de suelo y raíz. Las mayores densidades poblacionales promedio de *Pratylenchus* se registraron en las zonas de abastecimiento de los ingenios El Modelo y Mahuixtlán con 1 430 y 1 247 individuos por 50 g de raíz respectivamente. Los géneros identificados se asociaron principalmente con suelos de textura arcillosa y franca. No se encontró relación entre el porcentaje de materia orgánica del suelo y la presencia de géneros específicos. **Implicaciones**: Este estudio constituye el primer diagnóstico sobre la presencia de nematodos fitoparásitos en las principales regiones cañeras del estado de Veracruz. Es necesario evaluar el daño potencial de cada especie y establecer umbrales económicos considerando factores agronómicos y ambientales propios de cada región productora. **Conclusión**: Se confirmó la presencia de nematodos fitoparásitos en la rizosfera del cultivo de caña de azúcar, se destaca la predominancia del género *Pratylenchus,* el cual podría estar asociado con pérdidas en el rendimiento del cultivo.

Palabras clave: *Pratylenchus*; *Helicotylenchus*; plagas del suelo; diversidad; abundancia.

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is one of the most cultivated plants in the world, native to Southeast Asia, and is currently grown in more than 100 countries (Zhao *et al*., 2015). It is mainly planted to produce sugar, but it also produces paper, fibers, fertilizers, cement and ethanol (Bordonal *et al*., 2018). In 2023, around 2 billion tons were produced on more than 20 million hectares (FAO, 2023). Sugarcane is one of the main crops in Mexico, producing more than 55 million tons annually, with a value of more than 2.6 billion dollars, positioning the country as the sixth-largest producer worldwide (SIAP, 2024). The state of Veracruz is the main producer in Mexico, contributing nearly 40% of the national production. There are more than 350 thousand hectares planted and 18 sugar mills (CONADESUCA, 2025). Despite the economic relevance of sugarcane cultivation in Mexico, there is a significant shortage of research on phytosanitary issues, hindering the identification and effective management of pests. Furthermore, the inappropriate use of pesticides, among other agricultural practices, has generated health and environmental issues (Ramírez-Mora *et al*., 2019). Strengthening research on these topics is essential to ensure the sustainability of sugarcane production. Among the major pests affecting agricultural crops worldwide are plant-parasitic nematodes (Berry *et al*., 2017). There are currently more than 4,100 described species, and some represent a significant limitation for agricultural production. It is estimated that 10% of the food harvest is lost worldwide due to the effect of plant-parasitic nematodes (Varela-Benavides, 2018). There is a record of more than 275 species of plant-parasitic nematodes associated with the sugarcane rhizosphere (Westerdahl *et al*., 2023). Sugarcane plants affected by nematodes are difficult for farmers to diagnose because they present inconspicuous symptoms such as stunted growth, poor tillering, and patchy crop cover, therefore, these symptoms are commonly attributed to nutritional deficiencies, soil toxicity, or poor management practices (Manzanilla-López and Marbán-Mendoza, 2012). The most widely distributed plant-parasitic nematodes in sugarcane fields are *Helicotylenchus* spp., *Meloidogyne* spp. and *Pratylenchus* spp. (Martinha *et al*., 2022; Bhuiyan *et al*., 2024). In general, it is estimated that population densities of *Meloidogyne* spp. and *Pratylenchus* spp. above 150 nematodes per 100 g dry soil decrease yield by up to 30% (Bhuiyan *et al*., 2018; Chafloque, 2019; Severino *et al*., 2010). The monoculture and low tillage prevailing in sugarcane cultivation promote the development of high populations of plant-parasitic nematodes (Robles-Hernández and Pérez-Moreno, 2011), therefore, the intensive application of chemical nematicides is common, which, although effective if applied properly, are also the cause of various environmental pollution problems (Aguilar-Rivera, 2014; Toledo *et al*., 2008). In Mexico, studies on plant-parasitic nematodes associated with sugarcane are scarce. *Criconemoides* sp., *Helicotylenchus* sp. and *Pratylenchus* sp. have been reported as the most abundant genera, with densities of 31, 44 and 7000 nematodes per 100 cm^3 $soil^{-1}$, respectively, in sugarcane fields in central Veracruz (Desgarennes *et al*., 2011; Pantaleón and Gómez, 2012). In the sugarcane fields of Veracruz, the application of nematicides at the beginning of the crop cycle is a common practice since low yields in some areas are usually attributed to the presence of nematode populations even when a proper diagnosis has not been made (Cid del Prado-Vera *et al*., 2018). The first step in integrated pest management is to determine the identity of the organism and its population density. Therefore, the objective of this work was to identify plant-parasitic nematodes and their population density in the rhizosphere of *S. officinarum* in the sugarcane-growing regions of the Veracruz state.

MATERIALS AND METHODS

Collection sites

The study was carried out in the supply areas of the sugar mills Pánuco, El Higo, El Modelo, Mahuixtlán and Motzorongo, distributed in the four sugarcane growing-regions of Veracruz (Northeast, Central, Córdoba – Gulf and Papaloapan – Gulf) from March to May 2023 (Figure 1, Table 1). In each supply area, ten sugarcane fields of one hectare were selected and five samples composed of soil (500 g) and roots (100 g) distributed in a zigzag pattern were taken. The sugarcane plants were in the tillering stage at the time of taking the sample. For each composite sample, 10-m sections were delimited in five furrows, and four plant strains were taken from each furrow to obtain rhizospheric soil and roots at a depth between 20 and 25 cm. Using this method, five samples were obtained per plot, each consisting of 20 subsamples of soil and roots. The samples were placed in plastic bags, labeled with the data corresponding to each collection site and transferred to the Parasitology Laboratory of the Faculty of Agricultural Sciences of the Universidad Veracruzana in Xalapa, Veracruz. Additionally, the texture of the soil at each collection site was determined using the Bouyoucos method and the organic matter content was determined using the Walkley-Black method in accordance with the Mexican Official Standard 021 (SEMARNAT, 2000).

Extraction, identification and quantification of nematodes

The nematodes extraction from the soil was carried out by the sieving-centrifugation method and for the roots by the maceration-sieving-centrifugation method (Rosas-Hernández, 2014). The nematodes obtained were fixed in 4% formalin and transferred to glycerin by the Seinhorst method (1962) for mounting in a paraffin ring according to the protocol stipulated by SENASICA (2019). The identification of genera was carried out using morphological and morphometric methods, following the keys and taxonomic references of Siddiqi (2000) and Hunt *et al*. (2018). Once identified, the number of individuals per genus was quantified and the population density was expressed as the number of individuals in 100 g of soil and 50 g of root.

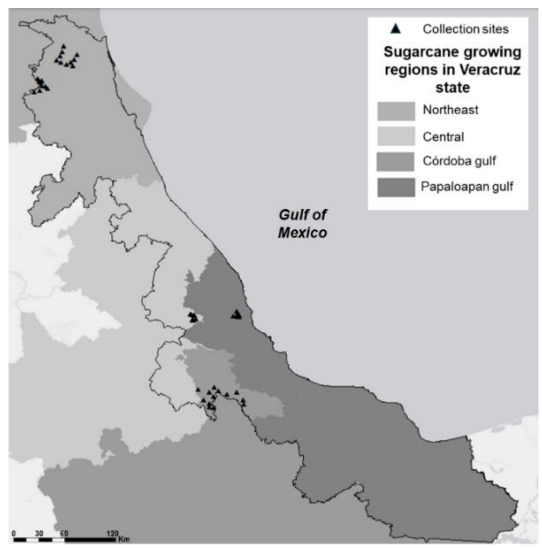

Figure 1. Collection sites in the supply areas of five sugar mills distributed throughout the sugarcane-growing regions of the Veracruz state.

Data analysis

The population density and relative abundance of each nematode genus were calculated at each sampling site. To describe the pattern of genus richness and abundance in the five sampled areas, the first Hill number (q0 richness) was estimated considering the genera of phytoparasitic nematodes independently for each collection site, since these metrics are designed to evaluate and compare diversity between communities (α-diversity). Each site represents an ecological unit with particular soil and management conditions, so analysis by site allows for an adequate ecological comparison between communities. Rarefaction and extrapolation curves including 95% confidence intervals were obtained by bootstrap resampling in the iNEXT software. Genus similarity between supply zones was analyzed by the Jaccard index using PAST software version 4.0. Finally, a principal component analysis (PCA) was performed to evaluate the relationship between soil texture, organic matter content and phytoparasitic nematode populations using InfoStat software version 2017. Prior to analysis, the data were standardized using z-score normalization (mean = 0, standard deviation = 1).

Table 1. General description of the collection sites in the sugar mills supply areas.

Municipality, sugar mill and location	Sugarcane varieties	Soil type	Climate and average tempera-ture	Average precipita-tion	Altitude (masl)
Pánuco, Pánuco 22°01'07.8"N 98°10'50.3"W	CP 72-2086, RD 7511, MEX 68-1345, MEX 79-471	Flat alluvial	Tropical subhumid, ~25–28 °C	~1,200–1,500 mm	10 m
El Higo, El Higo 21°46'23.5"N 98°27'19.9"W	CP 72-2086	Alluvial	Tropical humid, ~26–28 °C	~1,500–2,000 mm	20–70 m
La Antigua, El Modelo 19°22'39.7"N 96°22'18.5"W	MEX 69-290 MEX 79-471	Alluvial	Tropical humid, ~25–28 °C	~1,500–2,000 mm	23 m
Coatepec, Mahuixtlán 19°24'33.0"N 96°55'02.8"W	ITV 92-373 CP 72-2086	Andosol	Temperate-humid, ~18–22 °C	~1,500–2,000 mm	1,200–1,400 m
Tezonapa, Motzorongo 18°38'30.6"N 96°43'36.0"W	C 90-530, MOTZ-MEX 003461, ITV 92-1424, ITV 92-373, MEX 69-290, RD 7511, CP 72-2086	Ferralsols, luvisols and cambisols	Tropical subhumid, ~24–27 °C	~1,500–2,000 mm	200–300 m

Table made with data compiled from CONADESUCA, 2015, Fundación Heinrich Böll, 2019 and Castillo *et al*., 2018.

RESULTS AND DISCUSSION

Nine genera of plant-parasitic nematodes were found in the soil and four genera in the roots in the 50 sugarcane fields sampled in the state of Veracruz. The genera *Pratylenchus* (Figure 2 A-C), *Helicotylenchus* (Figure 2 D-F), *Criconemoides*, and *Hoplolaimus* were found in the five supply areas of the sugar mills; *Rotylenchus* was found in four supply areas, *Trichodorus* in three and *Aphelenchus*, *Psilenchus*, and *Throphurus* in two areas (Table 2). *Pratylenchus* and *Helicotylenchus* are commonly associated with sugarcane crops around the world (de Barros *et al*., 2017; Peña-Prades *et al*., 2018). Species of the genus *Pratylenchus* (migratory endoparasites) are considered the most pathogenic for sugarcane; *Pratylenchus zeae* and *Pratylenchus brachyurus* can reduce yield by more than 40% in areas with high population levels (Barbosa *et al*., 2013). *Helicotylenchus* species (semi-endoparasites) are considered moderately pathogenic for sugarcane crops and are frequently found in sugarcane fields in Brazil, Mexico and African countries (Afolami *et al*., 2014; Lopez-Lima *et al*., 2014; Bhuiyan *et al*., 2024; Dengia *et al*., 2024). Likewise, the genus *Criconemoides* is one of the most abundant nematodes in sugarcane crops in the Papaloapan-Gulf sugarcane growing region (Desgarennes *et al*., 2011; Lopez-Lima *et al*., 2014). It is noteworthy that *Criconemoides* species are vectors of phytopathogenic bacteria in other crops (Olson *et al*., 2017). Low populations of *Aphelenchus*, *Hoplolaimus*, *Trichodorus,* and *Throphurus* have been detected in sugarcane fields in the Caribbean and South America (Kleynhans and Cadet, 1994; Porto *et al*., 2018; Rodríguez-Carnero *et al*., 2020; Martinha *et al*., 2022). However, given that pathogenicity can vary between species of the same genus, morphological and molecular studies are needed to determine the nematodes present in sugarcane crops at the species level and clarify the potential damage.

Soil nematode population densities were different between sugar mill supply areas, ranging from 90 nematodes 100 g soil^{-1} at Motzorongo to 220 nematodes 100 g soil^{-1} at El Higo. The most abundant genus in the soil was *Helicotylenchus* with a relative abundance between 70 and 79% in the five areas sampled with average populations between 71 and 161 individuals 100 g soil^{-1} (Table 3). The population density of nematodes in 50 g of root ranged from 157 in Pánuco to 1,454 in El Modelo. The most abundant genus in the roots of the five areas sampled was *Pratylenchus* with a relative abundance between 81 and 98%. The sugarcane fields sampled in the supply areas of El

Figure 2. Plant-parasitic nematodes associated with sugarcane roots in Veracruz state. A-C *Pratylenchus* sp. female, A entire body, B anterior region with square cephalic frame and stylet (S), C tail region. D-F) *Helicotylenchus* sp. female A) entire body, B) anterior region with rounded cephalic frame and C) tail region with mucron (M). Scale bar: A and D=50 µm, B, C, E and F= 20 µm

Table 2. Genera of plant-parasitic nematodes identified in the supply areas of sugar mills in the state of Veracruz

Sugar mill	Diagnosis	
	Soil	Roots
Pánuco	*Criconemoides, Helicotylenchus, Hoplolaimus, Pratylenchus, Rotylenchus*	*Helicotylenchus, Pratylenchus*
El Higo	*Criconemoides, Helicotylenchus, Hoplolaimus, Pratylenchus, Rotylenchus*	*Aphelenchus, Helicotylenchus, Pratylenchus*
El Modelo	*Criconemoides, Helicotylenchus, Hoplolaimus, Pratylenchus, Psilenchus, Trichodorus, Trophurus*	*Criconemoides, Helicotylenchus, Pratylenchus,*
Mahuixtlán	*Aphelenchus, Criconemoides, Helicotylenchus, Hoplolaimus, Pratylenchus, Psilenchus, Rotylenchus, Trichodorus, Throphurus*	*Helicotylenchus, Pratylenchus*
Motzorongo	*Criconemoides, Helicotylenchus, Hoplolaimus, Pratylenchus, Rotylenchus, Trichodorus*	*Helicotylenchus, Pratylenchus*

Modelo and Mahuixtlán had the highest *Pratylenchus* population density with 1,430 and 1,247 individuals per 50 g of root, respectively (Table 4). According to the data, the central zone of the state has the highest population levels of *Pratylenchus*. More research is needed to determine if these populations are significantly damaging sugarcane production in Veracruz. Economic thresholds for *Pratylenchus* vary considerably between regions due to differences in agro-climatic conditions, cultivated varieties, sampling techniques, and economic criteria. In Brazil, the economic threshold for *P. zeae* in sugarcane is between 200 and 300 nematodes 100 cm³ soil^{-1}, depending on the soil type and the crop developmental stage (Severino *et al*., 2010). In Brazil, values above 4,000 nematodes 50 g root^{-1} are considered an economic threshold. However, these studies have focused on searching for tolerant or resistant varieties (Belle *et al*., 2017; Dinardo-Miranda *et al*., 2019). On the other hand, in Australia, economic thresholds for *Pratylenchus* start at 150 individuals 100 g soil^{-1} (Magarey, 2013) and consider predisposing conditions such as soil characteristics and monoculture. In addition, Australia has prioritized the use of early monitoring and preventive management systems, so thresholds are defined at more conservative levels to avoid population increases in the medium term (Stirling *et al*., 2011). Agronomic and economic factors partially explain the difference in economic thresholds between the two countries. Intensive production systems in Brazil can withstand higher levels of infestation before control is warranted, so thresholds are higher. In contrast, Australia tends to adopt a preventive strategy, reflected in thresholds that vary based on risk interpretation and prevailing agricultural practices. This underscores the need to adapt management decisions to local conditions and consider agronomic, economic, and environmental factors when setting specific thresholds for nematodes in sugarcane fields in Veracruz. However, we consider it necessary to monitor plant-parasitic nematode populations, as they pose a potential danger to the crop due to their possible increase in population and their interaction with other pathogens (Dinardo-Miranda and Fracasso, 2010; Martínez-Fernández *et al*., 2015).

The Hill numbers for sites sampled in Veracruz state indicate that Mahuixtlán has the highest richness of plant-parasitic nematode genera, and this figure increases slightly with increased sampling effort. Likewise, abundance could exceed 2,500 individuals (100 g soil^{-1} + 50 g root^{-1}). The El Modelo supply area presented the highest abundance, and the analysis indicates a trend of increasing richness up to 11 genera and more than 3,000 individuals (100 g soil^{-1} + 50 g root^{-1}). The sugarcane fields sampled in El Higo presented a medium richness, but it is estimated that up to 10 genera could be present. Although Pánuco and Motzorongo exhibited medium richness, the analysis indicates that there is no potential for significant increases in richness or abundance (Figure 3).

It is estimated that 65% of the genera of plant-parasitic nematodes diagnosed are shared by all sites, indicating a high degree of similarity in Jaccard's index. The El Modelo and Mahuixtlán sampling sites are over 90% similar. In turn, Pánuco and Motzorongo share 87% similarity, and El Higo exhibits 83% similarity with Pánuco and Motzorongo (Figure 4). The similarity between El Modelo and Mahuixtlán could be explained by the presence of the genera *Psilenchus* and *Trophurus*. Pánuco and Motzorongo are characterized by including nematode control among their agronomic management activities and this may influence the prevalence of certain genera such as *Pratylenchus* and *Helicotylenchus* with respect to other genera.

Table 3. Population density and relative abundance of plant-parasitic nematodes in sugarcane plantation soil in the supply areas of five sugar mills in Veracruz

	Sugar mills				
Nematode genera	**Pánuco**	**El Higo**	**El Modelo**	**Mahuixtlán**	**Motzorongo**
Aphelenchus	NF[1]	1 (0.2%)	2 (1%)	3 (2%)	NF
Criconemoides	4* (3%)[+]	9 (4%)	43 (20%)	12 (8%)	8 (8%)
Helicotylenchus	97 (77%)	161 (73%)	148 (70%)	103 (72%)	71 (79%)
Hoplolaimus	4 (3.5%)	2 (0.7%)	NF	5 (4%)	2 (2%)
Pratylenchus	19 (15%)	48 (22%)	16 (8%)	13 (9%)	5 (6%)
Psilenchus	NF	NF	1 (0.3%)	1 (1%)	NF
Rotylenchus	2 (1.5%)	1 (0.1%)	NF	2 (1%)	1 (2%)
Trichodorus	NF	NF	1 (0.5%)	3 (2%)	3 (3%)
Trophurus	NF	NF	1 (0.7%)	3 (2%)	NF

*Nematodes 100 g soil^{-1}; [+] relative abundance; [1] Not found

Table 4. Population density and relative abundance of plant-parasitic nematodes in sugarcane roots in the supply areas of five sugar mills in Veracruz

Nematode genera	Sugar mills				
	Pánuco	El Higo	El Modelo	Mahuixtlán	Motzorongo
Criconemoides	NF[1]	4 (0.5%)	10 (0.7%)	1 (0.1%)	NF
Helicotylenchus	26* (17%)[0]	34 (5%)	13 (0.9%)	18 (1.4%)	31 (19%)
Hoplolaimus	0.4 (0.3%)	1.2 (0.2%)	1 (0.1%)	4 (0.3%)	0.8 (0.5%)
Pratylenchus	131 (83%)	658 (95%)	1430 (98%)	1247 (98%)	136 (81%)

*Nematodes 50 g root^{-1}, [+]Relative abundance, [1]Not found

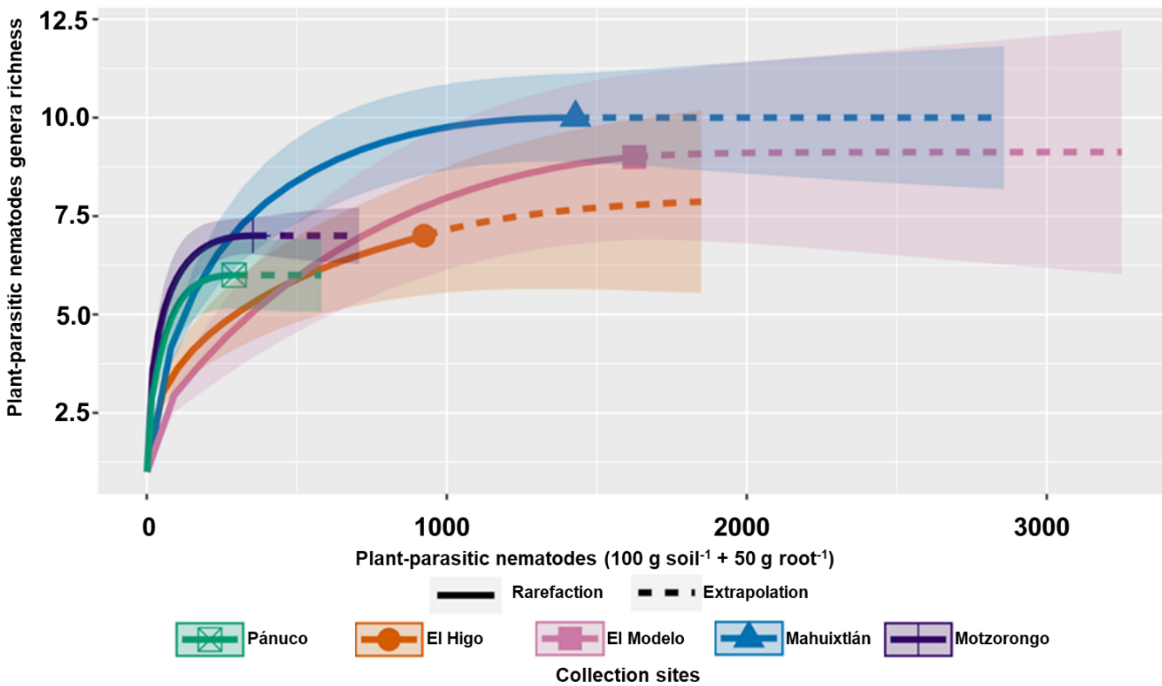

Figure 3. Analysis of the first Hill number (q0 = richness) for genera of plant-parasitic nematodes in the soil and root of sugarcane for each study site. The solid lines show estimates of genus richness, while the dotted lines and shaded bands indicate the 95% confidence intervals obtained using bootstrap resampling (iNext Software).

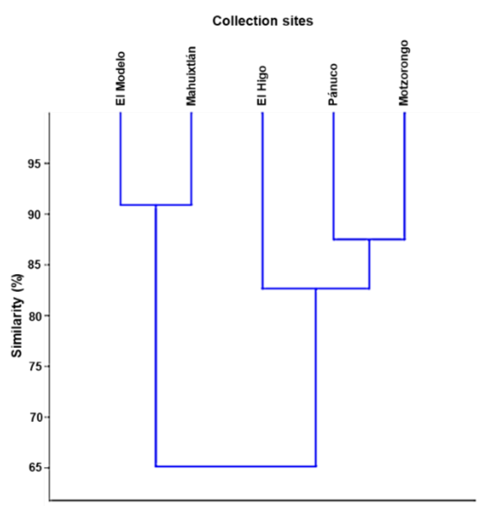

Figure 4. Cluster of genus similarity with respect to each sugarcane supply area.

Principal component analysis indicates that the genus *Hoplolaimus* is associated with a clayey texture. In contrast, the genera *Aphelenchus*, *Criconemoides*, *Pratylenchus*, *Psilenchus* and *Trophurus* exhibit a higher population frequency in textures such as clay, clay loam and sandy clay. The presence of *Helicotylenchus* is related to loam texture, while sandy loam and sandy clay loam textures are associated with the highest frequency of *Rotylenchus* (Figure 5A). Notably, this study found no correlation between the presence of nematode genera and sandy textures. This is because filiform nematodes are distributed in water films in the soil. Therefore, the greater the clay content, the greater the water retention and nematode presence (Holguin *et al*., 2015; Ndava *et al*., 2018). No specific pattern was found for the population frequency of the different genera found in sugarcane soil and the amount of organic matter. The genera *Pratylenchus*, *Psilenchus*, *Aphelenchus*,

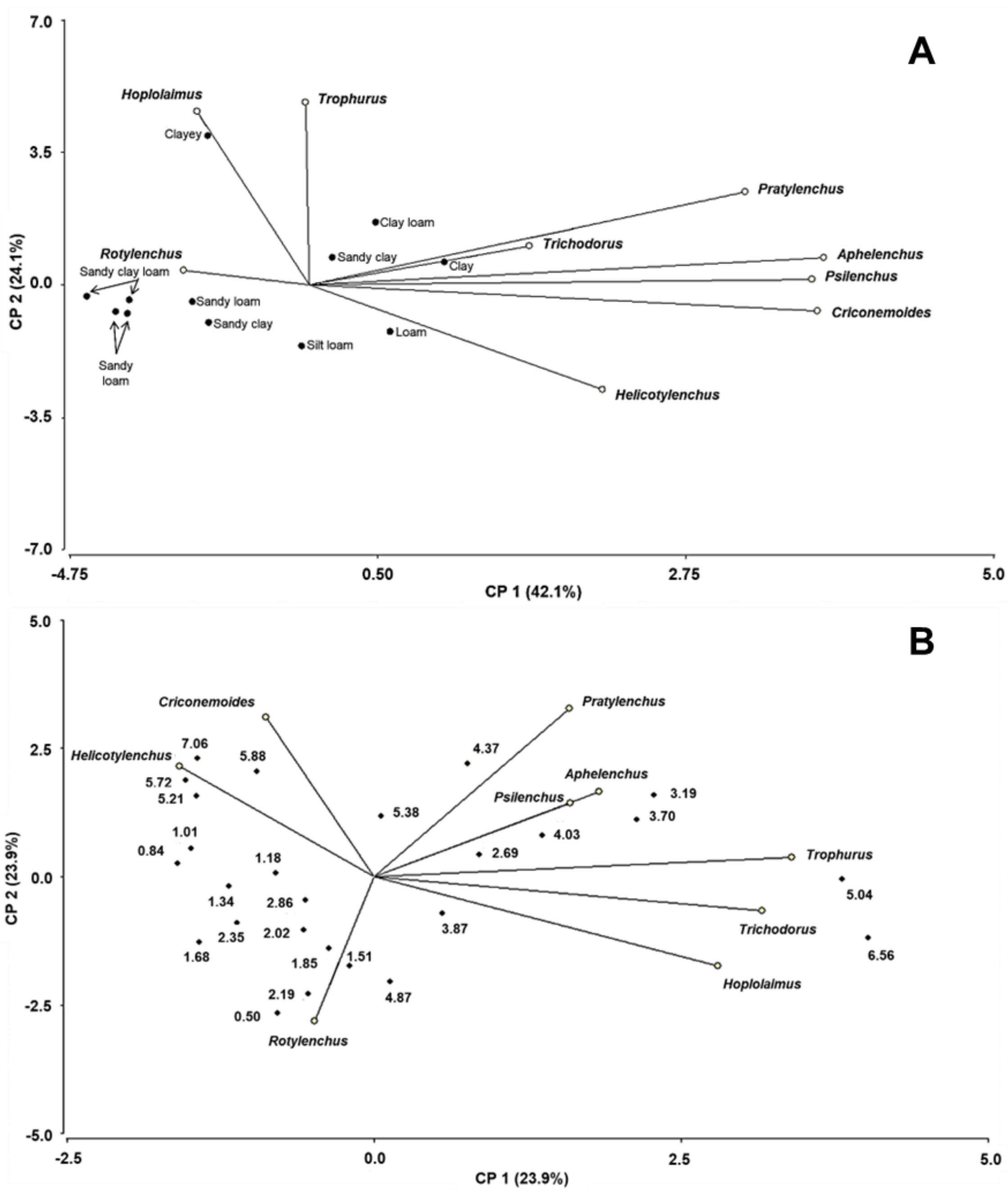

Figure 5. Principal component analysis between most abundant nematode genera in the sugarcane rhizosphere and A) soil texture and B) organic matter percentage.

Trophurus, *Trichodorus*, and *Hoplolaimus* were more prevalent in soils with organic matter percentages ranging from 2.69 to 6.56%, which is considered medium to high. *Rotylenchus*, *Criconemoides*, and *Helicotylenchus* correlate with organic matter percentages ranging from low to high, from 0.5% to 7.06% (Figure 5B). It has been reported that incorporating organic amendments into soil and applying green manures is correlated with a lower incidence of plant-parasitic nematodes in crops, likely due to increased soil microbial diversity, including natural enemies of plant-parasitic nematodes (Widmer *et al*., 2002; Tabarant *et al*., 2011). In sugarcane crops in Veracruz, being in intensive production schemes, it is possible that soil biodiversity is reduced despite the addition of organic matter, so it does not correlate with the presence of nematodes. Research on the diversity, abundance and distribution of plant-parasitic nematodes in sugarcane fields in the state of Veracruz has a significant impact on the long-term viability of this crop and related agribusiness, since it provides key information for decision-making in integrated pest management. The identification of the most prevalent genera, such as *Pratylenchus* and *Helicotylenchus*, as well as their population levels and their relationship with soil characteristics, will make it possible to establish economic thresholds and design specific and efficient control strategies for each region. This information also contributes to reducing the indiscriminate use of nematicides and promoting sustainable practices. Conversely, without this type of research, the sugarcane agroindustry faces the risk of undetected increases in nematode populations, significant economic losses, deterioration of soil health and the use of unsustainable control methods, all of which compromise the profitability and long-term sustainability of the crop.

CONCLUSIONS

This is the first study to diagnose the presence of plant-parasitic nematodes in the main sugarcane-growing regions of the state. The presence of plant-parasitic nematodes in the rhizosphere of sugarcane crops, particularly of the *Pratylenchus* genus, has been confirmed, and given the population density observed, this genus may be responsible for a reduction in crop yield. The presence of *Pratylenchus* represents a significant economic constraint on the sustainability and profitability of the sugarcane industry. Infestations lead to yield reductions, directly diminishing revenues for both producers and processors. Additionally, the need for increased investment in monitoring, diagnostic, and control measures, such as nematicides and alternative management strategies, raises production costs and further compromises economic viability. Consequently, the implementation of integrated pest management programs, supported by early detection and continuous surveillance, is essential to mitigate these economic losses and to ensure the long-term sustainability of sugarcane cultivation in the region. However, it is necessary to determine the potential damage caused by each species and to establish economic thresholds based on agronomic and environmental factors in each production region. Furthermore, future research should focus on the molecular determination of species and the evaluation of tolerant varieties, biological control strategies and crop rotation.

Acknowledgements
The first author thanks SECIHTI Mexico for a grant for postgraduate studies (PhD in Agricultural Sciences) at the Universidad Veracruzana (UV). We would like to thank the field technicians of the sugar mills for facilitating access to the plantations for sampling purposes.

Funding. No financial support was received to conduct this work.

Conflict of interest. The authors declare that they have no competing interests.

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 study of this article.

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

Author contribution statement (CRediT). **C.Y. Vásquez-González** – Sample acquisition, methodology writing first draft. **F. Hernández-Baz** – Conceptualization, validation, supervision. **A. Salinas-Castro** – Conceptualization, methodology, validation, supervision, writing. **N. Aguilar-Rivera** – Conceptualization, validation, supervision. **D. López-Lima** – Conceptualization, investigation, writing, validation, supervision.

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