UNDER PEER REVIEW

Original Research Article

Plant-Parasitic Nematodes (PPNs) Associated with Sugarcane (*Saccharum officinarum*) in Selected Areas of Northern Cebu, Philippines

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ABSTRACT

Plant-parasitic nematodes (PPNs) are reported to be associated with sugarcane and are considered detrimental to the crop, resulting to low quality produce and low yielding ability. This study aimed at identifying the plant-parasitic nematode genera associated with sugarcane, as well as its prevalence in the selected sampling sites of Northern Cebu, Philippines. Root and soil samples were collected from Bogo City (Phil99-1793 & VMC84-947), Medellin (VMC84-947 & Mauritius), and San Remigio (VMC84-947 & Mauritius). Nematodes from roots and soil rhizosphere were extracted following the standard methods and were identified up to genus level based on morphological characteristics. A total of eleven (11) plant-parasitic nematode genera (*Criconema*, *Ditylenchus*, *Filenchus*, *Helicotylenchus*, *Hoplolaimus*, *Meloidogyne*, *Pratylenchus*, *Rotylenchulus*, *Rotylenchus*, *Tylenchus*, and *Xiphinema*) which belong to nine different families were identified. Among these identified nematode genera, *Meloidogyne* were the most abundant in sugarcane roots, and *Helicotylenchus* in soil rhizosphere. However, no nematode genera recovered from the roots were considered prevalent as their frequency and abundance were too low, which occurred only in some localities. In roots, *Helicotylenchus* was the predominant nematode genera due to its high frequency of occurrence in all sampling sites and high abundance in two sampling sites. Other identified nematode genera were less prevalent as observed in their relatively low abundance and frequency of occurrence. These results may advance farmers' knowledge on plant-parasitic nematodes associated with sugarcane in their locality and assess appropriate control measures in mitigating them.

Keywords: Plant-parasitic nematodes, morphological characteristics, abundance, frequency, prevalence

1. INTRODUCTION

Sugarcane (*Saccharum officinarum L.*) is a tall, perennial grass that belongs to the *Poaceae/Gramineae* family and is considered as one of the most important plantation crops grown in tropical and subtropical regions of the world, including the Philippines. It is propagated primarily by means of cuttings. Seed cane is spaced at 1.4 to 1.8 meters (4.5 to 6 feet) apart at densities of 10,000 to 25,000 per hectare (Yamane, 2023). Aside from sugar as its main product, it also produces extensive by-products such as biofuels, ethanol, straw, bagasse (cane fibers), molasses, and rum (Yamane, 2023).

According to Manzoor et al. (2023), approximately 28.3 million hectares are planted with sugarcane in more than 90 countries with a total production of about 1.69 billion tons worldwide. Brazil, India, and the European Union are considered as the top sugarcane-producing countries which contribute to 40% of the total worldwide production (Anandh, 2018). In the Philippines, out of the approximately 30M ha. of the country's total land area, sugarcane production is planted to about 422, 500 ha. with average annual yield of 57 tons/ha., contributing an annual revenue of about PhP 70 billion (Tobias, 2020). Based on the Sugar Regulatory Administration's (SRA) sugar policy for crop year 2020-2021, 93% of the total output would go to domestic markets and 7% to the US (USDA, 2021).

With favorable conditions, growing cultivated areas, and increasing productivity rates amidst the pandemic, infestations of pathogenic diseases in sugarcane have been a constant problem which is prevalently increasing. Extreme consideration of its security is needed because it is considered as a top export commodity. One major pathogen causing defects to sugarcane are the nematodes that feed mostly on the roots of the plant. Nematodes are small worms that cause serious damage to sugarcane (Blair et al., 1999). Symptoms of nematodes in sugarcane depend on the genus and include reduced root and shoot mass, reduced tillering, stunted, sparse and distorted roots, and less obvious symptoms such as necrosis and discoloration of roots (Ramouthar & Bhuiyan, 2018). Tillering is reduced and the height of the canopy may vary considerably because shoot elongation is affected. Below ground, swellings and galls are relatively easy to see on primary roots and the fine root system (Stirling, 2023).

Sugarcane in South Africa hosts more than 90 species of 28 genera of plant-parasitic nematodes (PPNs). The more common species include *Helicotylenchus dihystera, Pratylenchus zeae, Xiphinema elongatum* and on sandy soils, *Meloidogyne javanica,* which caused an estimated 9% loss of production (Berry et al., 2017). Several studies have uncovered PPN diversity in sugarcane fields in other countries such as Mauritius (Spaull, 1990), India (Sundararaj & Mehta, 1993), Kenya (Chirchir et al., 2008), South Africa (Berry et al., 2017), and Brazil (Noronha et al., 2017), revealing the most common PPN genera associated with sugarcane as *Meloidogyne*, *Pratylenchus*, *Tylenchorhynchus*, *Rotylenchulus*, and *Helicotylenchus* (Singh et al., 2020).

In the Philippines, there are few studies on plant-parasitic nematodes (PPNs) associated with sugarcane. In Negros Occidental and Panay Island, *Tylenchorynchus* was the most predominant nematode genera associated with sugarcane (Husmillo et al., 1983). Knowledge on the identification and prevalence of PPNs associated with sugarcane are important in order to know how they cause reduction in yield and to assess which appropriate control measures are effective in mitigating them. This study aimed to identify the PPN genera associated with sugarcane in Northern Cebu, Philippines through morphological characteristics and to determine the prevalent PPNs in the area based on population density, frequency, and abundance.

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2. MATERIALS AND METHODS

2.1 Sampling Sites and Location of the Study

Root and soil samples were collected from three sugarcane production areas in Northern Cebu (Bogo, Medellin, and San Remigio) on February 2023 (Figure 1). In each municipality, three sugarcane fields were randomly sampled and soil characteristics (texture, pH, temperature, moisture), sugarcane varieties grown, and management practices employed were recorded (Table 1). In each field, root samples were taken from five sample plants that showed symptoms of nematode infection (i.e., stunted growth, leaf discoloration, chlorosis/yellowing, necrosis, galling, root lesions, and shortened roots) which were collected by excavation using a digging bar. The roots were then separated from the cane and were placed in plastic bags, labeled, and stored properly. Approximately 200 grams of soil samples were also collected from the soil rhizosphere of each plant, up to 15 cm depth using hand trowel and bolo. These soil samples were placed in plastic bags, labeled, and stored properly. The samples were brought to the Crop Protection laboratory of Cebu Technological University – Barili Campus for extraction and identification.

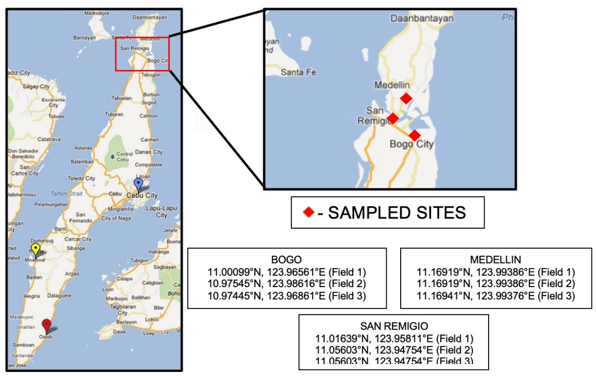

Fig 1. Sampling sites in Northern Cebu, Philippines

Table 1. Soil texture, pH, temperature, moisture, sugarcane varieties grown, and practices employed in the sampling sites

Sampling Sites	Soil Texture	Soil pH	Temperature	Soil Moisture	Variety	Practices after Harvest
Bogo	Clayey	6.8	23	Dry	Phil99-1793, VMC 84-947	Trash Burning / Mulching
Medellin	Loamy Clay	6.6	23	Normal	VMC 84-947, Mauritius	Trash Burning / Mulching
San Remigio	Sandy Loam	4.5	23.8	Normal	VMC 84-947, Mauritius	Trash Burning / Mulching

2.2 Extraction of Nematodes from Plant Roots

Nematode extraction was done at the Crop Protection laboratory of the Department of Agriculture and Food Science, Cebu Technological University – Barili Campus. Plant root samples were washed with running water and were cut into small pieces, approximately up to 1 cm using a pair of scissors. Then, 5g of cut roots were macerated for about six seconds using a blender. The macerated roots were placed into a wire mesh lined with tissue paper and were placed over a bowl following a modified Baermann tray method. Water was added to the tray just enough to touch the bottom part of the mesh to get a clear suspension. Then, the set-up was incubated for 48 hrs. and application of water mists were done whenever necessary to avoid drying up.

2.3 Extraction of Nematodes from Soil

Soil samples were mixed thoroughly and 200 mL representative were processed using a combination of decanting and sieving (using a 212 µm and 53 µm aperture size) methods followed by incubation in modified Baermann tray method. The soil was placed in a wire mesh lined with tissue paper which were placed over into a dish water and left at room temperature for 48 hrs.

2.4 Preservation of Nematodes

After the specified extraction time, nematode suspensions were collected into test tubes and were allowed to settle for 12 hrs. The supernatant was sucked using a pipette to reduce the volume of suspension. Nematodes were killed and fixed by adding hot 4% formalin (65°C-70°C) into the nematode suspensions. Preserved nematodes were placed in the refrigerator until identification and assessment of population density.

2.4 Identification of Plant-Parasitic Nematodes

The extracted nematodes from soil and root samples were manually picked using a picking needle from the clear suspension under a stereomicroscope and were mounted to glass slide with a drop of water, covered with cover slip and sealed with colorless nail polish to prevent drying up of mounts. Plant-parasitic nematodes were identified to genus level following keys and references of Siddiqi (2006), Mekete et al. (2012), and others.

2.4 Assessment of Nematode Population Density and Prevalence

Population densities of plant-parasitic genera from root and soil samples per plant per sampling site were determined in three 5 ml aliquots in a counting dish under a stereomicroscope (Olympus, Germany). Nematode counts were expressed as 5g/roots and per 200 ml soil.

The prevalence of plant-parasitic nematode genera in roots and soil were determined using the relationship between abundance index (AI) and frequency (F) of occurrence computed using the formula:

$$\text{Abundance (AI)} = \log \frac{\text{total number of nematodes per gram roots or L soil in all positive samples}}{\text{number of positive samples}}$$

$$\text{Frequency (F)} = \frac{\text{number of samples positive with nematodes}}{\text{total number of samples}} \times 100$$

Based on the limits established by Fortuner and Merny (1973), a nematode was regarded as abundant if abundance ≥ 1.3 (20 individuals/g of roots) and abundance ≥ 2.3 (200 individuals/L of soil) in roots and soil, respectively. A nematode was regarded as frequent in the soil or roots when observed in at least 30% of the samples.

3. RESULTS AND DISCUSSION

3.1 Plant-Parasitic Nematode Genera Associated with Sugarcane

Various plant-parasitic nematode (PPN) genera were found from the root and soil samples of sugarcane in the selected sites of Northern Cebu, Philippines (Table 2). A total of eleven (11) genera of PPNs belonging to seven (7) different families were found associated with sugarcane in the surveyed fields. PPNs found include *Criconema* (*Criconimatidae*), *Ditylenchus* (*Anguinidae*), *Filenchus* (*Tylenchidae*), *Helicotylenchus* (*Hoplolaimidae*), *Hoplolaimus* (*Hoplolaimidae*), *Meloidogyne* (*Heteroderidae*), *Pratylenchus* (*Pratylenchidae*), *Rotylenchulus* (*Hoplolaimidae*), *Rotylenchus* (*Hoplolaimidae*), *Tylenchus* (*Tylenchidae*), and *Xiphinema* (*Longidoridae*). Of these genera, *Filenchus*, *Meloidogyne*, *Helicotylenchus*, and *Pratylenchus* were found associated with roots of sugarcane plants and all genera were present in the soil rhizosphere except *Meloidogyne* and *Filenchus*.

The nematode genera identified in this study were also reported in previous works conducted in the Philippines as well as in other countries. Davide (1988) reported four (4) major nematode genera associated with sugarcane in the country. Davide (1988) observed that *Meloidogyne incognita* bannered the species that were present in the collected samples of sugarcane-growing areas in the country, followed by *Tylenchorhynchus martini, Rotylenchulus reniformis, and Pratylenchus zeae*. In another study, *Tylenchorhynchus*, *Helicotylenchus*, *Pratylenchus*, and *Xiphinema* were observed to be predominant plant-parasitic nematode genera infecting sugarcane crops in Negros and Panay Island (Husmillo et al., 1983). These reported nematode genera were also found to occur in sugarcane crops in Northern Cebu with the exception of *Tylenchorhynchus*.

In Kilimanjaro region of Tanzania, Singh et al. (2020) revealed the presence of seven plant-parasitic nematode (PPN) genera; *Helicotylenchus, Hemicyliophora, Pratylenchus, Rotylenchulus, Scutellonema, Meloidogyne, and Tylenchorhynchus* after they performed morphological and molecular analyses of PPNs from 12 sugarcane plantation sites of Tanganyika Planting Company (TPC). Four of these nematode genera (*Helicotylenchus*, *Meloidogyne*, *Pratylenchus*, and *Rotylenchulus*) were also found to occur in the sugarcane fields of Northern Cebu, Philippines.

In Paraná, Brazil, Martinha et al. (2022) reported that *Pratylenchus*, *Meloidogyne*, *Helicotylenchus*, *Xiphinema*, *Hoplolaimus*, *Tylenchus*, and *Ditylenchus* were some of the nematode genera that caused damages to the sugarcane-growing areas. These nematode genera were also observed in the present study, suggesting that these nematodes are commonly associated with sugarcane production.

Table 2. Soil texture, pH, temperature, moisture, sugarcane varieties grown, and practices employed in the sampling sites

Roots		Rhizosphere	
Family	**Genus**	**Family**	**Genus**
Heteroderidae	*Meloidogyne*	*Anguinidae*	*Ditylenchus*
Hoplolaimidae	*Helicotylenchus*	*Criconimatidae*	*Criconema*

Pratylenchidae	*Pratylenchus*	*Hoplolaimidae*	*Hoplolaimus* *Helicotylenchus* *Rotylenchus* *Rotylenchulus*
Tylenchide	*Filenchus*		
		Longidoridae *Pratylenchidae* *Tylenchidae*	*Xiphinema* *Pratylenchus* *Tylenchus*

3.2 Genus Identification

Morphological identification yielded 11 genera of plant-parasitic nematodes (PPNs) associated with sugarcane in Northern Cebu, Philippines. The important diagnostic characters that aid in the genus identification are herein presented:

Genus: *Criconema* (Mekete et al., 2012) (Figure 2)
Annuli smooth or variously ornamented, annuli of labial region smooth; labial region usually with six pseudolips wide and clearly set off the next body annulus; tail conoid-pointed to bluntly-rounded.

Fig 2. Genus: *Criconema* (A, 10x) whole body; (B, 100x) anterior; and (C, 100x) posterior

Genus: *Ditylenchus* (Siddiqi, 2000) (Figure 3)
Body usually under 1.5 mm long, not curving strongly when relaxed; mature adults slender; tails elongate-conoid to subcylindrical or filiform.

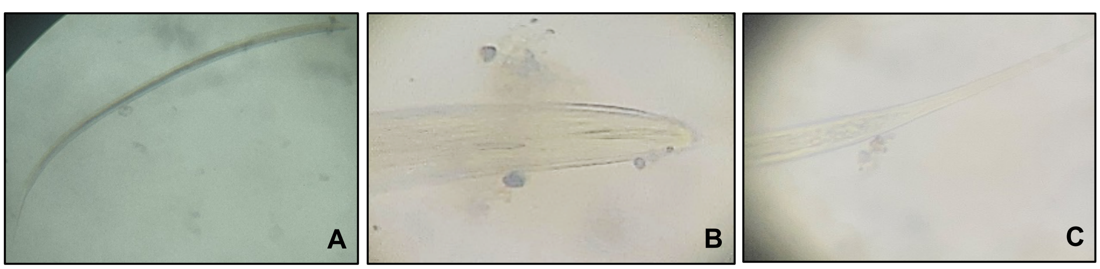

Fig 3. Genus: *Ditylenchus* (A, 10x) whole body; (B, 100x) anterior; and (C, 100x) posterior

Genus: *Filenchus* (Siddiqi, 2000) (Figure 4)

Body small to moderately large (0.3-1.3 mm), straight to arcuate when relaxed. Cephalic region broadly-rounded or conoid-rounded; tails generally filiform and straight, may be elongate-conoid and slightly ventrally arcuate but not hooked.

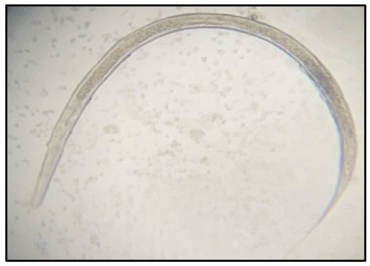

Fig 4. Genus: *Filenchus* whole body (40x)

Genus: *Helicotylenchus* (Steiner, 1949) (Figure 5)

Spirally-colloid or rarely arcuate; stylet robust; tail asymmetrical or hemispherical, short, dorsally-convex conoid; vulva located at 70% of the total body length.

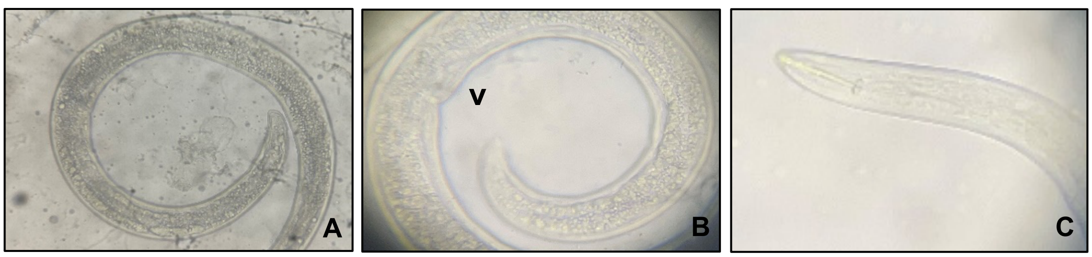

Fig 5. Genus: *Helicotylenchus* (A, 40x) whole body; (B, 100x) female mid-body region showing the vulva (v); and (C, 100x) anterior

Genus: *Hoplolaimus* (Daday, 1905; Siddiqi, 2000) (Figure 6)

Body arcuate or spiral-shaped; rounded stylet knobs, devoid of tooth-like projections; labial disc lemon-shaped or spindle-shaped; annulated female tail.

Fig 6. Genus: *Hoplolaimus* (A, 10x) whole body; (B, 100x) anterior; and (C, 40x) posterior

Genus: *Meloidogyne* (Eisenback, J. & Triantaphyllou H., 1991) (Figure 7)
Vermiform (male); rounded cephalic region, few annules; rounded tail, blunt tail tip (first stage juvenile) and vermiform, migratory and infective (second stage juvenile).

Fig 7. Genus: *Meloidogyne* whole body (40x)

Genus: *Pratylenchus* (Siddiqi, 2000) (Figure 8)
Rounded stylet; anteriorly flat or indented basal knobs; terminus rounded (rarely pointed) tail, sub-cylindrical to conoid (female); terminus smooth or annulated.

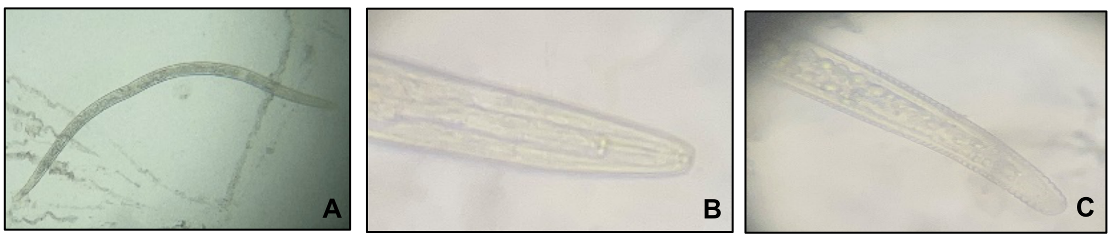

Fig 8. Genus: *Pratylenchus* (A, 10x) whole body; (B, 100x) anterior; and (C, 100x) posterior

Genus: *Rotylenchulus* (Siddiqi, 2000) (Figure 9)
Small-sized (usually 0.5 mm or under); cephalic region continuous, with or without distinct annules; male stylet weaker than that of females; tail elongate-conoid; slender spicule in males.

Fig 9. Genus: *Rotylenchulus* (A, 10x) whole body; (B, 100x) posterior showing the male spicule; and (C, 100x) anterior

Genus: ***Rotylenchus*** (Siddiqi, 2000) (Figure 10)

Cephalic region elevated, offset or continuous, round or truncate anteriorly, finely annulated; labial disc flat; stylet well-developed in both sexes; female tail cylindroid to dorsally convex-conoid.

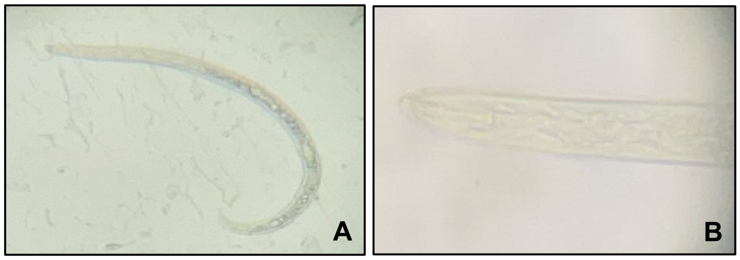

Fig 10. Genus: *Rotylenchus* (A, 10x) whole body; (B, 100x) anterior

Genus: ***Tylenchus*** (Siddiqi, 2000) (Figure 11)

Small to medium-sized (0.4-1.3 mm), ventrally-curved upon relaxation; cephalic region continuous, annulated; tail ventrally-arcuate; spicules cephalated, arcuate; cloacal lips slightly raised.

Fig 11. Genus: *Tylenchus* (A, 10x) whole body; (B, 100x) posterior; and (C, 100x) anterior

Genus: ***Xiphinema*** (Mekete et al., 2012; Tarjan, 1964) (Figure 12)

Stylet long, straight, tapering to a long slender point with long extensions; body long, stylet extensions with sclerotized basal flanges; shorter, conical, and digitate tail.

Fig 12. Genus: *Xiphinema* (A, 10x) whole body; (B, 100x) posterior; and (C, 100x) anterior

3.3 Population Density of Plant-Parasitic Nematode (PPN) Genera Associated with Sugarcane

Population densities of plant-parasitic nematodes associated with sugarcane in roots and soil differed (Figure 13). It can be noted that population densities of plant-parasitic nematodes from root samples were generally low that ranged only from 2 to 11 per 5g roots. *Meloidogyne* had the highest population density (11/5g roots) followed by *Filenchus* (10/5g roots), while *Pratylenchus* and *Helicotylenchus* had a population density of 3 per 5g roots and 2 per 5g roots, respectively. In soil, *Helicotylenchus* (127/200 ml soil) was the predominant nematode genera followed by *Xiphinema* (91/200 ml soil), and *Hoplolaimus* (71/200 ml soil). The rest of the nematode genera (*Criconema*, *Ditylenchus*, *Pratylenchus*, *Rotylenchulus, Rotylenchus*, and *Tylenchus)* were recovered at lesser densities that ranged from 3 to 38 per 200 ml soil.

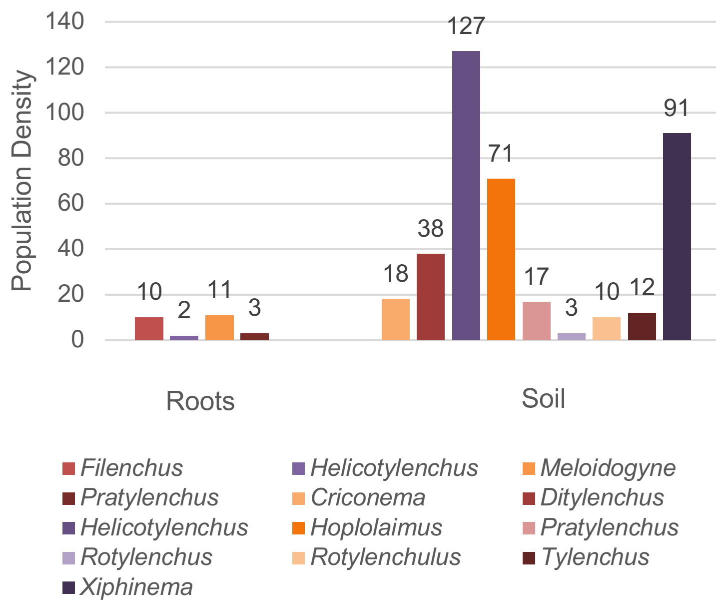

Fig 13. Population density of plant-parasitic nematode (PPN) genera associated with roots and soil of sugarcane grown in Northern Cebu, Philippines

Population densities of nematode genera recovered from sugarcane roots were generally low which can be attributed to several factors. It was noted in this study that the sample plants were already ratooned twice or thrice and mostly aged at 11-12 months. In Queensland, Australia, Blair et al. (1999) found out that nematode population densities were significantly higher in the roots of plant crops than ratoon crops, specifying the *Pratylenchus* genera. Similarly, in Australia and Burkina Faso, Berry et al. (2007) observed that ratoon crops were less susceptible than plant crops as its root systems became stronger and more rigid as it aged. In soil, higher population densities were observed. McSorley (2019) stated that soil is an excellent and is one of the natural habitats for plant-parasitic nematodes, and 100 cc of soil may contain several thousands of them. In addition, Ramadhani et al. (2022) validated that *Helicotylenchus*, a migratory ectoparasite (Rathore, 2017), was one of the important nematode genera associated with sugarcane. In his research on the phytonematodes associated with sugarcane, *Helicotylenchus* was one of the major nematode genera recovered based on the highest absolute population, which was also the frontrunner along with *Pratylenchus* in Brathwaite's (1980) study.

Plant-parasitic nematodes that were found at low densities might be due to the management practices of the farmers from Northern Cebu as they employ the "kaingin" system/trash burning and trash mulching. "Kaingin" was also referred to as 'slash and burn' by farmers in Matalom, Leyte (Lawrence et al., 1997). On the other hand, trash mulching was a common practice in sugarcane production that helped protect the soil as it minimized and/or prevented soil erosion (Samson et al., 2001). After harvest, 90% of the sugarcane farmers in Northern Cebu usually employ trash burning and the remaining 10% employ trash mulching as their means of land clearing and preparation for the next cropping season. In addition, once sugarcane has been established, they do not employ any form of weed management or pest control until harvest. According to Song (2023), a 4-year study of Bastow (2020) revealed that fire reduces soil nematode population by 76% in a semiarid grassland. As a response, Song (2023) investigated the effects of short-term prescribed fire on soil nematode communities and soil properties in an old-field grassland in Northern China which resulted to an increased soil nematode population by 77% and genus richness by 49%. For a more precise control of nematode population, Stirling (2023) recommended crop rotation, use of resistant and tolerant cultivars, nematicide application, and use of natural enemies or biocontrol agents like nematode-trapping fungi, soil microarthropods (nematophagous mites - *Protogamasellus sp.*), and bacteria in the genus *Pasteuria*.

The predominant nematode genera recovered in this study (*Helicotylenchus*) were considered as ectoparasites (Marmonier, 2019) which live outside the roots of sugarcane. Contributing to higher population densities, eggs of these plant-parasitic nematodes may remain dormant in the soil for a few months until conditions are favorable.

3.4 Prevalence of Plant-Parasitic Nematode (PPN) Genera Associated with Sugarcane

Based on frequency and abundance, prevalence of plant-parasitic nematodes in roots and soil rhizosphere of sugarcane varied (Figure 14). Based on the limits by Fortuner and Merny (1973), no nematode genera were considered as prevalent in roots as none reached the limit (AI, 1.3 and F,30%). Abundance index of the four nematode genera ranged only from 0.3 to 1, while the frequency of occurrence was 11% (*Filenchus*, *Meloidogyne*, and *Pratylenchus*) and 22% (*Helicotylenchus*) which were both below the threshold limits. In soil, *Helicotylenchus* and *Xiphinema* were the most prevalent nematode genera (AI, 2.33 and 2.53, respectively; F, 100% and 44%, respectively) as they surpassed the limits (AI,2.3 and F, 30%) set by Fortuner and Merny (1973). Similarly, Ramadhani et al. (2022) also observed that *Helicotylenchus* was the most prevalent nematode genera in Rajawali II, West Java. Román (1961) also revealed that *Helicotylenchus* was the most prevalent nematode genera in the selected fields of sugarcane in Central Soller and San Sebastián, Puerto Rico. *Xiphinema* was also noted to be prevalent in South Africa (Berry et al., 2008) and in Mauritius (Lamberti et al., 1987). *Criconema*, *Ditylenchus*, *Hoplolaimus*, and *Pratylenchus* were also regarded as frequent nematodes of sugarcane soil rhizosphere as their frequencies ranged from 33% to 89%, which were beyond the frequency limit (30%). However, these nematode genera were considered as omnipresent pathogens (Pascual et al., 2017; Fortuner and Merny, 1973) because of their abundance that ranged only from 1.65 to 2.28, which were below the threshold limit (2.3) in soil.

Among the nematode genera identified in this study, *Filenchus*, *Meloidogyne*, *Rotylenchulus*, *Rotylenchus*, and *Tylenchus* were considered as fortuitous parasites (Pascual et al., 2017; Fortuner and Merny, 1973) which do not cause economic loss due to low frequency and abundance as described by Fortuner and Merny (1973).

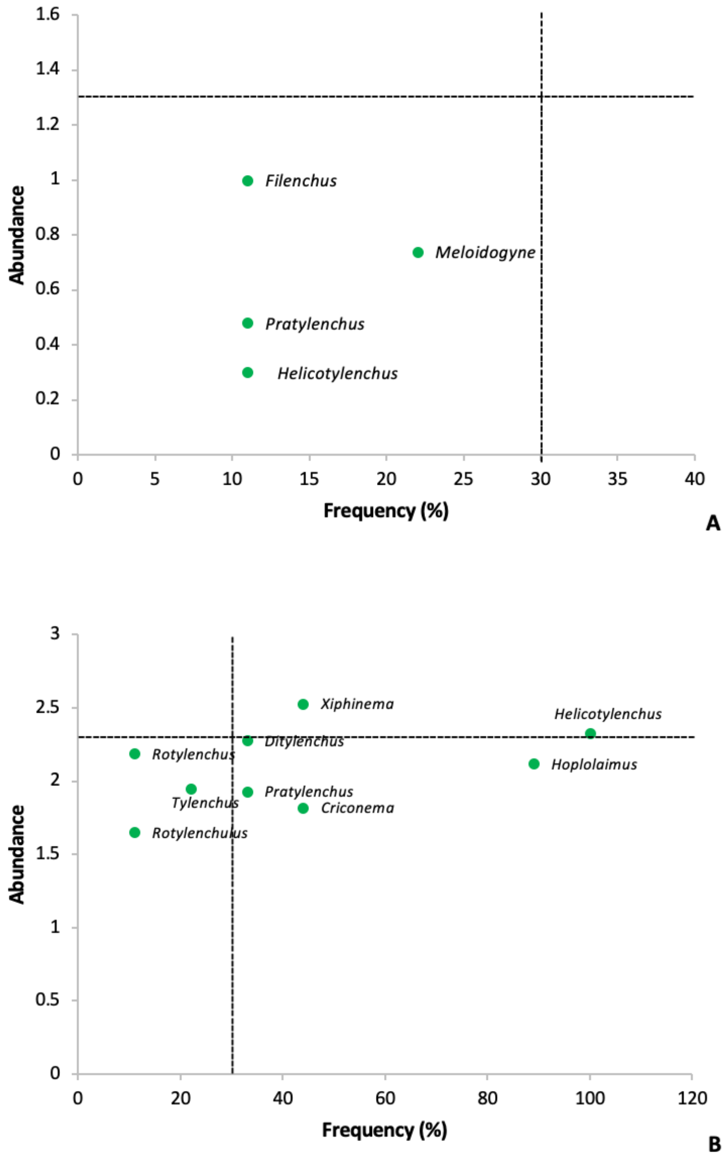

Figure 14. Frequency and abundance of plant-parasitic nematodes (PPNs) in sugarcane roots (A) and soil rhizosphere (B)

3.5 Occurrence and Abundance of Plant-Parasitic Nematode (PPN) Genera Associated with Sugarcane in the Localities

Nematode genera recovered from the different municipalities varied in frequency of occurrence and abundance (Table 3). In Bogo, the observed nematode genera were present in more than 30% of the fields surveyed but their abundance were generally low. In Medellin, *Helicotylenchus*, *Hoplolaimus*, and *Xiphinema* were frequent and abundant. *Ditylenchus* and *Pratylenchus* were also frequent but had low abundance. Other nematode genera were not recovered from the sampled sites. In San Remigio, all nematode genera were frequent except

Filenchus and *Meloidogyne*. In the sampled site, *Helicotylenchus* and *Ditylenchus* frequently occurred and were found to be abundant. *Helicotylenchus* was considered as potential pathogen as it was prevalent in all locations except in Bogo. The rest of the nematode genera were frequent but had very low abundance index from the different locations, which identified them as omnipresent nematodes.

Table 3. Occurrence and abundance of plant-parasitic nematodes (PPNs) associated with sugarcane in different sampling locations in Northern Cebu, Philippines

Genus	Bogo	Medellin	San Remigio
Criconema	+		+
Ditylenchus		+	+++
Filenchus	+		
Helicotylenchus	+	+++	+++
Hoplolaimus	+	+++	+
Meloidogyne	+		
Pratylenchus		+	+
Rotylenchulus			+
Rotylenchus			+
Tylenchus	+		+
Xiphinema	+	+++	+

Notes: + = frequent (present in more than 30% of the fields surveyed); ++ = abundant (AI ≥ 1.3/5g roots; AI ≥ 2.3/L soil); and +++ = frequent and abundant (F ≥ 30% and AI ≥ 2.3/L soil).

The study of Martinha et al. (2022) stated that the difference between the frequency of occurrences may be associated with the environmental factors, temperature, water content of the soil, sugarcane cultivar, and management adopted by producers that interfere with the density and frequency of genera associated with the sugarcane rhizosphere (Bond et al., 2000; Matinha 2022).

In terms of soil type, the result of this study showing high presence of different nematode genera in San Remigio (Table 3) may be associated with its sandy loam type of soil (Table 1) which nematodes prefer more than any other type of soil (Warner, 2009).

In correlation with the physicochemical parameters of soil (water holding capacity, moisture content, pH, electrical conductivity, and temperature), Gade et al. (2018) surveyed the nematode diversity in sugarcane fields of Aurangabad District in India. It appeared that temperature and electrical conductivity provided positive correlation to nematode diversity. Whereas to pH, it had a negative correlation. It was noted in this study that the pH of the three municipalities varied (Table 1), leading to the idea that as extremophiles (Sapir, 2021), plant-parasitic nematodes can survive in soils over wide ranges of pH (Warner, 2009).

4. CONCLUSION

Different plant-parasitic nematodes which differ in densities and prevalence are in association with sugarcane. Identified plant-parasitic nematodes include *Criconema*, *Ditylenchus*, *Filenchus*, *Helicotylenchus*, *Hoplolaimus*, *Meloidogyne,* *Pratylenchus*, *Rotylenchulus*, *Rotylenchus*, *Tylenchus*, and *Xiphinema*. No nematode genera recovered are considered prevalent in sugarcane roots due to low abundance index and frequency of occurrence. *Helicotylenchus* are the most prevalent plant-parasitic nematodes in soil rhizosphere, which could cause significant yield loss in sugarcane production if not properly managed. These results can further farmers' knowledge on plant-parasitic nematodes associated with sugarcane in their locality.

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