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DIVERSITY AND DISTRIBUTION OF PHYTONEMATODES IN PINEAPPLE CROPS (Ananas comosus) IN DAGUA, VALLE DEL CAUCA, COLOMBIA

H.L. Sánchez–Ramírez[1], J.O. Cardona-Montoya[2], C.E. Arboleda-Riascos[2*]

[1]Student, Agronomy Program, Universidad del Pacífico, Buenaventura, Valle del Cauca, Colombia; Orcid ID: https://orcid.org/0009-0000-6205-108X Email ID: hlsanchez@unipacifico.edu.co
[2]Professor, Agronomy Program, Universidad del Pacífico, Buenaventura, Valle del Cauca, Colombia. Orchid ID: https://orcid.org/0000-0001-5676-9044 Email ID: jocardona@unipacifico.edu.co
[2]Professor, Agronomy Program, Universidad del Pacífico, Buenaventura, Valle del Cauca, Colombia. Orchid ID: https://orcid.org/0009-0006-0335-0307 Email ID: carboleda@unipacifico.edu.co*

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Corresponding Author: C.E. Arboleda-Riascos (carboleda@unipacifico.edu.co)

ABSTRACT

The cultivation of Ananas comosus is of major economic importance in tropical regions; however, its sustainability is constrained by the presence of plant-parasitic nematodes. In this context, the objective of this study was to characterize the diversity, distribution, and population structure of nematodes associated with pineapple crops in Dagua, Valle del Cauca (Colombia), through the analysis of ecological parameters and morphological traits. Systematic sampling was conducted in six commercial farms, collecting soil (0–20 cm depth) and root samples. Soil samples were processed using sieving and decantation techniques, whereas root samples were processed by maceration. Taxonomic identification was based on morphological characters observed under light microscopy. The results revealed the presence of nematodes in all soil samples and in most root samples. The genera Meloidogyne spp. and Helicotylenchus spp. were predominant, showing clear differences in their spatial distribution. In soil, Helicotylenchus exhibited the highest relative density (62.07%), associated with its ecto- and semi-endoparasitic behavior, whereas in roots Meloidogyne reached a significant density (35.66%), consistent with its sedentary endoparasitic habit. Free-living nematodes were also detected in both compartments, indicating active soil biological processes. Morphologically, Meloidogyne was characterized by a robust stylet and a tail with a hyaline terminus in juveniles, while Helicotylenchus showed a spiral-shaped body at rest and a rounded tail. Ecological parameters indicated a community with high frequency of occurrence and differential dominance among genera, whose coexistence increases phytosanitary risk. Therefore, integrating morphological and ecological analyses is essential for designing sustainable management strategies in pineapple production systems.

KEYWORDS: plant-parasitic nematodes; *Meloidogyne*; *Helicotylenchus*; population dynamics; phytosanitary risk.

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INTRODUCTION

Pineapple (*Ananas comosus* L.) cultivation is one of the most economically important tropical fruit production systems worldwide. Native to the region between southern Brazil and Paraguay in South America, it was domesticated by indigenous populations and later spread throughout tropical America and the Caribbean (SIAP, 2018). Currently, Costa Rica leads global pineapple production and exports, followed by Thailand, the Philippines, China, Brazil, India, and Indonesia (FAOSTAT, 2023). In Colombia, Agronet (2025) reports that in 2024 more than 13,000 hectares of pineapple were cultivated, with 11,533.01 hectares harvested and a total production of 354,641.87 tons, corresponding to an average yield of 41.06 tons per hectare. The departments with the highest production were Meta, Valle del Cauca, Antioquia, Santander, Guaviare, and Quindío (Agronet, 2025), highlighting the strategic importance of this crop across different regions of the country.

In southwestern Colombia, the department of Valle del Cauca has become a major agricultural hub, where pineapple represents a significant component of fruit production. In 2016, pineapple accounted for 24.98% of the department's fruit production, and an increasing trend in cultivated area has been observed (Díaz et al., 2022). Municipalities such as Dagua have strengthened their productive dynamics around this agricultural system, reflecting its economic and sociocultural relevance. However, the sustainability of pineapple cultivation is constrained by phytosanitary problems associated with pests and pathogens, including mealybugs (*Dysmicoccus brevipes*), thrips (*Hanseniella* spp.), and fungi such as *Phytophthora* and *Fusarium*. Additional constraints include bacteria belonging to the genus *Dickeya* and plant-parasitic nematodes from genera such as *Meloidogyne*, *Rotylenchulus*, *Helicotylenchus*, *Pratylenchus*, and *Criconemoides* (Vásquez et al., 2022; Bridge & Starr, 2007).

Plant-parasitic nematodes are microscopic soil-dwelling parasites that directly affect the root system of pineapple, causing deformities, necrosis, reduced root development, chlorosis, wilting, and a decline in fruit size and quality (Sasser & Freckman, 1987; Jones et al., 2013). This damage compromises the plant's ability to absorb water and nutrients and increases its susceptibility to secondary infections by other plant pathogens. Under high infestation conditions, yield losses may reach up to 74% (Oblitas, 2022), underscoring the need for systematic studies to understand their population dynamics and economic impact.

In this context, the analysis of ecological parameters such as frequency, density, abundance, and dominance is essential to characterize the structure and spatial distribution of plant-parasitic nematode communities in agroecosystems (Magurran, 2004; Cano, 2021). The evaluation of these indicators provides a robust scientific basis for decision-making in integrated management programs and contributes to the development of more efficient and sustainable control strategies. Therefore, the objective of this study is to characterize the plant-parasitic nematode community associated with pineapple cultivation in the municipality of Dagua, Valle del Cauca, through the analysis of ecological parameters. This will generate key information to strengthen phytosanitary management and improve the productivity of the system.

MATERIALS AND METHODS

Study area

The study was conducted in the municipality of Dagua, located on the western slope of the Valle del Cauca department in Colombia. Situated between 3°38′45″ N and 76°41′30″ W, the area lies within a transition zone between the Western Andes mountain range and the Pacific coastal region. This region is characterized by agroecological conditions favorable for pineapple (*Ananas comosus* L.) cultivation.

Sampling was carried out in six commercial pineapple farms located in Puerto Dagua (Medio Limón, Las Camelias, Portobelo, Los Pinos, Villa Suiza, and San Joaquín). Samples were processed at the Microbiology Laboratory of Universidad del Pacífico, Buenaventura, Colombia. The specific geographic coordinates of each farm were recorded using GPS and are presented in Table 1.

Table 1. Geographic coordinates and location of sampled farms in Dagua municipality.

municipality	Farm	Latitude	Longitude
Puerto Dagua	Medio limón	3° 41´06 "	76° 59´59"
	Las camelias	3° 59´ 01"	76° 50´ 18"
	Portobelo	3° 50´ 22"	76° 59´ 19"
	Los pinos	3° 58´ 49"	76° 58´19"
	Villa suiza	3° 36´ 38"	76° 56´ 54"
	San Joaquín	3° 41´ 05"	76° 57´ 57"

Source: Authors.

Sampling design and sample collection

A systematic reconnaissance sampling was conducted in six pineapple-producing farms, following methodological guidelines for nematological studies in perennial crops (Márquez, 2020; Rodríguez, 2020). In each field, longitudinal transects were performed along crop rows, leaving intervals of five rows unsampled to ensure spatial representativeness.

Per hectare, 20 subsamples of soil and roots were collected at a depth of 0–20 cm within the rhizosphere and at the base of the plants. Subsamples were homogenized to form a composite sample per plot. The material was packed in labeled plastic bags and transported in refrigerated thermal containers to the laboratory for processing within 24 hours after sampling.

Extraction of plant-parasitic nematodes from soil

Soil nematodes were extracted using the modified Cobb sieving and decantation method (Cobb, 1918; Coyne et al., 2018). From each composite sample, three replicates of 100 cm^3 of soil were taken and suspended in 1 L of water, then agitated for 5 minutes to release nematodes from soil particles. The suspension was allowed to settle for 1 minute and then passed through a series of sieves (30, 270, 325, and 400 mesh). The material retained on the 325 and 400 mesh sieves was collected and transferred to a decantation system using facial tissue, where it remained undisturbed for 48 hours to allow active nematode migration into the recovery water (Coyne et al., 2018).

Extraction of plant-parasitic nematodes from roots

Root nematodes were extracted using the maceration technique (Coyne et al., 2018). Roots were carefully washed to remove adhering soil. Three replicates of 10 g of fresh root tissue were prepared and macerated in 200 mL of water for 5 seconds at low speed to avoid damage to diagnostic structures. The homogenate was filtered through a series of sieves (30, 270, 325, and 400 mesh). The material retained on the 325 and 400 mesh sieves was collected in 100 mL of water and placed in a decantation system for 48 hours. Nematodes were then recovered in a final volume of 20 mL using a 400 mesh sieve and stored in Falcon tubes at 4 °C until quantification and identification.

Morphological identification was performed under a light microscope, considering diagnostic features such as stylet morphology, labial region, esophagus–intestine junction, tail shape, and resting body posture (Nguyen et al., 2019; Siddiqi, 2000).

Quantification and population analysis

Quantification was performed by taking 3 mL aliquots from each suspension, which were placed in counting chambers and examined under a light microscope. Three independent readings were conducted per replicate.

Populations were characterized using ecological parameters commonly applied in plant-parasitic nematode community studies (Fourie et al., 2020; Sikora et al., 2021):

i. **Absolute frequency (AF)** = (Number of samples containing the nematode / Total number of samples evaluated) × 100

ii. **Relative frequency (RF)** = (AF of the nematode / Σ AF of all nematodes) × 100

iii. **Absolute density (AD)** = Average number of individuals per 100 cm^3 of soil or 10 g of roots

iv. **Relative density (RD)** = (AD of the nematode / Σ AD of all nematodes) × 100

v. **Absolute prominence value (APV)** = AD × √AF

vi. **Relative prominence value (RPV)** = (APV / Σ APV of all nematodes) × 100

RESULTS AND DISCUSSION

Population levels of plant-parasitic nematodes

In the six farms evaluated in the municipality of Dagua, the presence of plant-parasitic nematodes was confirmed in all soil samples and in four out of six root samples. The predominant genera were *Meloidogyne* spp. and *Helicotylenchus* spp., recognized as common components of the nematode fauna associated with pineapple cultivation in tropical regions (Coyne et al., 2018; Sikora et al., 2018). In soil, *Helicotylenchus* reached the highest densities in Los Pinos (44 individuals/100 g) and Villa Suiza (22 individuals/100 g), whereas *Meloidogyne* reached its maximum in Portobelo (16 individuals/100 g). These inter-farm variations reflect differences in soil texture, organic matter content, water regime, and management practices, factors widely documented as drivers of plant-parasitic nematode population dynamics (Norton, 2019; Ferris et al., 2001).

The edaphic predominance of *Helicotylenchus* is consistent with its biological strategy as a migratory ectoparasite and semi-endoparasite. This genus feeds externally on epidermal and cortical cells, favoring its persistence in the rhizosphere and its recovery in soil samples (Siddiqi, 2000; Norton, 2019). In contrast, *Meloidogyne* showed higher frequency in roots, where sedentary females induce the formation of giant cells and galls that disrupt root physiology (Sikora et al., 2018).

In roots, *Meloidogyne* reached up to 12 individuals/100 g in Medio Limón and Las Camelias, whereas *Helicotylenchus* reached 26 individuals/100 g in Villa Suiza. The absence of both genera in roots from Los Pinos and San Joaquín, despite their presence in soil, suggests possible differences in varietal susceptibility, crop age, or microenvironmental conditions that limit parasite penetration and establishment (Brunes et al., 2024).

From an epidemiological perspective, the coexistence of both genera increases phytosanitary risk, as lesions caused by *Helicotylenchus* may facilitate secondary colonization by fungal and bacterial pathogens, while *Meloidogyne* directly compromises water and nutrient uptake (Coyne et al., 2018; Sikora et al., 2018). Studies conducted in Costa Rica (Hernández et al., 2014), Venezuela (Jiménez et al., 2001), and Colombia (Márquez, 2020) have documented similar patterns, consolidating these genera as the main plant-parasitic nematodes associated with pineapple in Latin America.

Taxonomic identification based on morphological characters

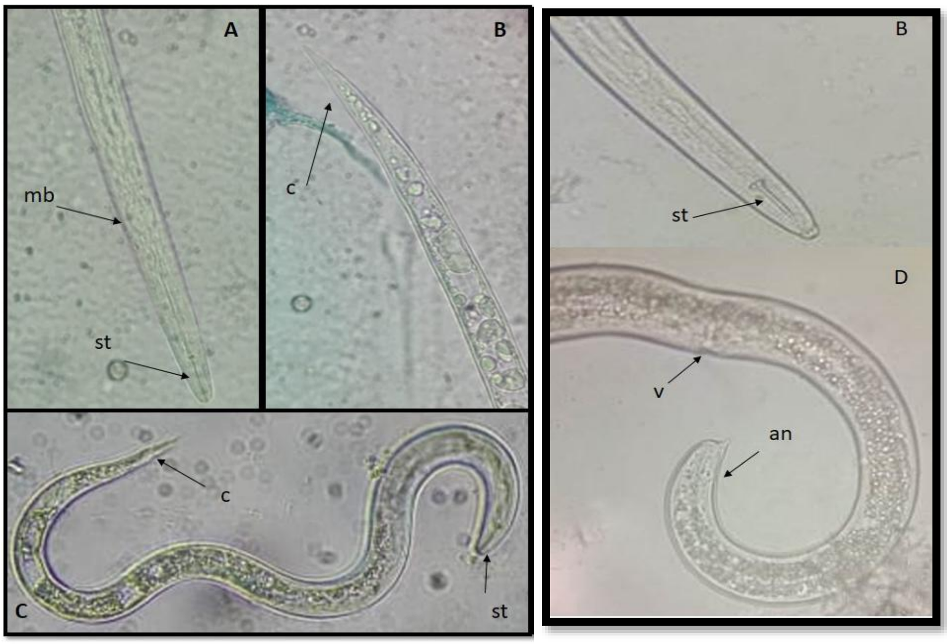

Figure 1. ***Plant-parasitic nematodes. A: anterior region of*** **Meloidogyne** ***sp.; B: posterior region of*** **Meloidogyne** ***sp.; C: whole body of*** **Meloidogyne** ***sp.; D: posterior region of*** **Helicotylenchus** ***sp.; E: anterior region of*** **Helicotylenchus** ***sp.; F: posterior region of*** **Meloidogyne** ***sp.*** **st*****: stylet;*** **v*****: vulva;*** **an*****: anus;*** **mb*****: median bulb.***

In *Meloidogyne*, second-stage juveniles (J2) exhibited a robust stylet with well-defined basal knobs and a tapered tail with a hyaline terminus. These features are diagnostic for distinguishing this genus from other members of Tylenchida (Perry et al., 2009). *Helicotylenchus* displayed a spiral-shaped body at rest, a short and strong stylet, a vulva located in the mid-posterior region, and a rounded tail, consistent with previous descriptions of the genus (Siddiqi, 2000).

Although morphological identification at the genus level was reliable, species-level delimitation within *Meloidogyne* requires perineal pattern analysis or molecular tools due to the phenotypic plasticity of the group (Castillo & Vovlas, 2007; Janssen et al., 2016).

Ecological parameters and community dominance

Table 2. Ecological parameters of plant-parasitic nematodes in soil and root samples.

pineapple (***Ananas comosus***)						
Genus	Absolute Frequency (%)	Relative Frequency (%)	Absolute Density (100g/soil)	Relative Density (%)	Absolute Prominence Value	Relative Prominence Value
Meloidogyne	100,00	35,29	6,00	24,83	60,00	0,26
Helicotylenchus	83,33	29,41	15,00	62,07	136,93	0,60
Free-living	100,00	35,29	3	13,10	31,67	0,14
	283	***100***	***24***	***100***	***229***	***1***
pineapple (***Ananas comosus***)						

Genus	Absolute Frequency (%)	Relative Frequency (%)	Absolute Density (10g/roots)	Relative Density (%)	Absolute Prominence Value	Relative Prominence Value
Meloidogyne	66,67	33,33	12	35,66	93,90	0,36
Helicotylenchus	66,67	33,33	14,00	43,41	114,31	0,43
Free-living	66,67	33,33	7	20,93	55,11	0,21
	200	**100**	**32**	**100**	**263**	**1**

Source: Authors.

Population levels in soil and roots

	Locality	Farm	*Meloidogyne*	*Helicotylenchus*	Free-living
Soil	Puerto Dagua	Medio limón	2	0	4
		Las Camelias	2	6	2
		Portobelo	16	3	1
		Los Pinos	5	44	5
		Villa Suiza	7	22	4
		San Joaquín	4	15	3
	Locality	**Farm**	***Meloidogyne***	***Helicotylenchus***	**Free-living**
Roots	Puerto Dagua	Medio limón	12	0	16
		Las Camelias	12	7	6
		Portobelo	11	23	3
		Los Pinos	-	-	-
		Villa Suiza	11	26	2
		San Joaquín	-	-	-

The structure of the nematode community associated with *Ananas comosus* showed a clear differentiation between soil and root compartments, reflecting the influence of ecological niche and parasitic habit on taxa distribution. This pattern has been widely documented in tropical systems, where the rhizosphere acts as an ecological gradient conditioning nematode abundance and activity (Shahid et al., 2024).

In soil, the dominance of *Helicotylenchus* (62.07% relative density) and its high absolute frequency suggest that this genus constitutes a key structural component of the soil nematode community in the evaluated system. Its ecological success has been attributed to its feeding plasticity (ectoparasitism and semi-endoparasitism) and its ability to persist under diverse edaphic conditions and management systems (Correia et al., 2026). This behavior is consistent with reports in perennial tropical crops, where *Helicotylenchus* can reach high population densities without necessarily inducing immediate visible symptoms, complicating early diagnosis.

In contrast, although *Meloidogyne* showed an absolute frequency of 100% in soil, its lower relative density (24.83%) suggests a homogeneous distribution but with more restricted populations in this compartment. This finding is consistent with its biology as a sedentary endoparasite, whose infective stage occurs in soil but whose development and reproduction take place within the root (Villarreal-Pérez et al., 2025).

In roots, the observed pattern reinforces this interpretation. Although *Helicotylenchus* maintained the highest relative density (43.41%), the significant presence of *Meloidogyne* (35.66%) confirms its active establishment within the root system. This genus is recognized for its high damage potential, associated with the induction of specialized feeding sites that alter plant physiology (Maleita et al., 2023), leading to reduced vigor and yield in pineapple crops.

Additionally, recent studies have shown that *Meloidogyne incognita* can modify the soil microbiome to facilitate host location, highlighting its adaptive capacity in the rhizosphere (Wu et al., 2026).

The presence of free-living nematodes, with high frequency in soil (100%) and lower frequency in roots (66.67%), suggests a system with active biological functioning. Although their relative density was lower, these organisms play a key role in nutrient mineralization and in regulating microbial communities, indirectly influencing the dynamics of plant-parasitic nematodes (Afzal & Mukhtar, 2024).

In the Colombian context, these results are consistent with those reported by Márquez et al. (2020), who documented the high prevalence of genera such as *Meloidogyne* and *Helicotylenchus* in tropical agricultural systems, highlighting their phytosanitary importance and wide distribution across crops. The coexistence of multiple nematode genera under local edaphoclimatic conditions increases management complexity and the risk of yield losses.

Overall, the findings suggest that *Helicotylenchus* may play a more relevant role than traditionally assumed, particularly due to its high abundance in soil and its capacity for root colonization. Nevertheless, *Meloidogyne* remains the primary risk agent due to its direct impact on plant physiology. This coexistence underscores the need for integrated management strategies that consider the entire nematode community.

Finally, the results confirm the importance of combined soil and root sampling to avoid underestimation of population levels, especially in systems where nematodes with different parasitic strategies coexist. This approach is essential for designing more precise and sustainable management strategies for pineapple cultivation in Colombia.

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