Cultivos Tropicales, Vol. 46, No. 1, January-March 2025, e-ISSN: 1819-4087, p-ISSN: 0258-5936, https://ediciones.inca.edu.cu

Cu-ID: https://cu-id.com/2050/v46n1e13

Artículo original

Plant parasitic nematodes associated to selected accessions in *Musa* spp. Cuban germplasm collection

Fitonematodos asociados a accesiones seleccionadas de la colección cubana de germoplasma de *Musa* spp.

Vániert Ventura Chávez[1*], Belkis Peteira Delgado-Oramas[2], Lianet González Díaz[1], Daine Hernández-Ochandía[2], Ileana Miranda Cabrera[2], Roberto Enrique Regalado[2], Mayra G. Rodríguez Hernández[2]

[1]Instituto de Investigaciones de Viandas Tropicales (INIVIT), Apartado 6, Santo Domingo, CP 53000, Villa Clara, Cuba.

[2]Centro Nacional de Sanidad Agropecuaria (CENSA). Apartado 10, San José de las Lajas, Mayabeque, Cuba.

ABSTRACT: The field plant genetic resource banks are *ex situ* collections that contribute to the preservation of plant germplasm. In Cuba, a collection of *Musa* spp., a genus of plants that are affected by pests of phytoparasitic nematodes, is kept. The objective of the research was to determine the plant parasitic nematodes and the dominant generas associated with 22 selected accessions at the germplasm collection of *Musa* spp. in Cuba, kept at the Tropical Root and Tubers Research Institute (INIVIT, according its acronyms in Spanish). The accessions were 'Burro CEMSA', 'Manzano Vietnamita', 'Pisang Ceilan', 'CEMSA ¾', 'INIVIT PV-2011', 'INIVIT PB-2012'', 'Yangambí', 'Gran Enano', 'Gross Michel', 'Pisang Jari Buaya', 'Calcuta 4', 'FHIA-18', 'INIVIT PV-0630', 'Enano Guantanamero', 'Macho ¾', 'FHIA-21', 'SH 3436-L-9', 'FHIA-01', 'FHIA 01-V1', 'SH 3142', 'SH 3362' and 'FHIA-17'. Sampling was carried out and soil and roots were collected from accession and were transferred to Agricultural Nematology Laboratory at National Center for Plant and Animal Health (CENSA, according its acronyms in Spanish), where processed by Whitehead Tray and maceration-sifting methods. Extracted nematodes were killed and fixed with TAF. The identification of genera was made using taxonomic keys and populations by genus were quantified. The dominant genera were determined using the ecological indexes: frequency, density and prominence value. Fifteen genera of nematodes were identified in soil samples and nine in roots. The genera *Meloidogyne* and *Helicotylenchus* were predominant. The largest populations of *Meloidogyne* in roots were found in 'Yangambí' and 'FHIA-18'; while *Helicotylenchus* was present in higher populations in the accessions 'INIVIT PV-0630' and 'CEMSA 3/4'.

Key words: Germplasm bank, *Helicotylenchus*, *Meloidogyne*, plant parasitic nematodes, root knot nematode, spiral nematode.

RESUMEN: Los bancos de recursos fitogenéticos en campo, son colecciones *ex situ* que contribuyen a preservar germoplasma vegetal. En Cuba, se custodia una colección de *Musa* spp., género de plantas que son afectadas por plagas de nematodos fitoparásitos. El objetivo de este estudio fue determinar los fitonematodos asociados a 22 accesiones seleccionadas en esa colección. Las accesiones fueron 'Burro CEMSA', 'Manzano Vietnamita', 'Pisang Ceilan', 'CEMSA ¾', 'INIVIT PV-2011', 'INIVIT PB-2012'', 'Yangambí', 'Gran Enano', 'Gross Michel', 'Pisang Jari Buaya', 'Calcuta 4', 'FHIA-18', 'INIVIT PV-0630', 'Enano Guantanamero', 'Macho ¾', 'FHIA-21', 'SH 3436-L-9', 'FHIA-01', 'FHIA 01-V1', 'SH 3142', 'SH 3362' y 'FHIA-17'. Se recolectaron muestras de suelo y raíces de las accesiones y las muestras se trasladaron al Laboratorio de Nematología Agrícola del Centro Nacional de Sanidad Agropecuaria, donde se procesaron por los métodos de Bandeja de Whitehead y maceración-tamizado. Los nematodos extraídos se mataron y fijaron con TAF. Para la identificación de géneros se utilizaron claves taxonómicas y se cuantificaron las poblaciones. Se determinaron los géneros dominantes mediante los índices ecológicos: frecuencia, densidad y valor de prominencia. Se identificaron 15 géneros de nematodos en muestras de suelo y nueve en raíces. Los géneros *Meloidogyne* y *Helicotylenchus* fueron predominantes. Las mayores poblaciones de *Meloidogyne* se encontraron en raíces de 'Yangambí' y 'FHIA-18'; mientras que, *Helicotylenchus* se presentó, en mayores poblaciones, en el suelo en las accesiones 'INIVIT PV-0630' y 'CEMSA ¾'.

Palabras clave: banco de germoplasma, *Helicotylenchus*, *Meloidogyne*, nematodos parásitos de plantas, nematodos agalleros, nematodo de espiral.

*Autor para correspondencia: vaniertvc1983@gmail.com

Received: 31/01/2025

Accepted: 15/03/2025

Conflict of interest: Authors have no conflict of interest.

Author Contributions. Vániert Ventura Chávez: **Research, Data curation, Writing -original draft. Writing - original draft.** Belkis Peteira Delgado-Oramas: **Conceptualization, Project management, Supervision, Writing: Proofreading and Editing**. Lianet González Díaz: **Conceptualization, Research.** Daine Hernández Ochandía: **Research.** Ileana Miranda Cabrera: **Formal analysis.** Roberto Enrique Regalado: **Research.** Mayra G. Rodríguez Hernández: **Conceptualization, Supervision, Writing: Revision and editing**.

INTRODUCTION

The banks of phytogenetic resources in the field are *ex situ* collections used to preserve the germplasm of plant species (1). The Tropical Root and Tuber Research Institute (INIVIT) is the custodian of the germplasm collection of *Musa* spp. in Cuba, and this institution is one of the eight organizations worldwide that, since the last decade (2010-2020), has a genetic breeding program for *Musa* spp. (2). The collection is planted every five years, rotating its position in INIVIT areas, as a tactic to diminish the effect of pests and nutritional deficiencies (3).

Plant parasitic nematodes (PPN) or phytoparasites are important pests of *Musa* spp. and affect accessions and cultivars in the *ex situ* and field collections, respectively (4). The study of these organisms is essential for their management, in order to reduce the harmful impact of these pests on the development and yield of cultivars.

In the 80s and 90s of the last century, PPN were the object of intense study by Cuban specialists, which led to the design and implementation, with favorable results, of the Integrated Management of Nematodes (IMN) in bananas and plantains (5). However, changes in the composition of genotypes in the country require new studies due to the possible impact of these pests on plant development in the field.

Knowing the PPN associated with various accessions protected in the National Collection of *Musa* spp. will offer elements to evaluate, in advance, that will happen to these accessions when the collection is established in a new location of the institute and to suggest tactics for the adequate management of these pests. The objective of this study was to determine the phytonematodes associated with 22 selected accessions, existing in the Cuban collection of *Musa* spp.

MATERIALS AND METHODS

Visit and sampling at the National Collection of *Musa* spp. guarded by INIVIT (22.35º N; 80.13º W), located in Santo Domingo, Villa Clara province, Cuba, took place in February 2018. The collection was established on a carbonated fluffy brown soil, according to the Cuban Soil Classification (6). The initial sampling for the study of soil characteristics and the determination of the properties that characterize the fertility of the arable horizon of the soil were previously reported by other authors (7) (Table 1).

The data of meteorological variables, corresponding to the year before sampling (2017) were taken from the Agrometeorological Station No. 326, attached to the Institute of Meteorology of Cuba and located at INIVIT (22º 35' N, 80º 18' W; 40 m.a.s.l.), Santo Domingo municipality, Villa Clara, Cuba. The temperature values were between a minimum of 20 ºC and a maximum of 30.6 ºC, with a mean of 24.6 ºC, the relative humidity had a mean of 80 % and the accumulated value of precipitation in that year was 1766.6 mm.

The collection maintained between 2015 and 2020 had 355 accessions from Vietnam, Honduras, Philippines, India, Guadeloupe, Jamaica and Cuba. The accessions were established in plots consisting of six seedlings, at a distance of 3.6 x 2.50 m, in a total area of 2.12 ha. The plants in the collection received the agro-technical care indicated in the Technical Instructions of the crop (8); although, with a deficient management of the weeds.

For this study, 22 accessions of *Musa* spp. were selected (Table 2), considering their relevance for the genetic improvement program of plantains and bananas developed by INIVIT and their importance in agricultural production in the country, covering accessions whose primary use in the diet is to obtain fruits (dessert) and others that are consumed cooked. To determine the geolocation of each accession in the collection, a portable global positioning device (GPS) Garmin® model Inreach Explorer was used.

From each plant, sub-samples of rhizospheric soil (~ 300 g) and roots (~ 50 g) were extracted at three equidistant points about 20 - 30 cm from the pseudostem of the mother plant (preferably “flowering” or with bunch), at a depth of up to 30 cm (9). With the soil and roots of each accession, separate samples (of soil and roots) were formed, placed in polyethylene bags, labeled and transported, in refrigerated containers, to the Laboratory of Agricultural Nematology of the National Center for Plant anad Animal Health (CENSA) (22°59'29.1 “N 82°09'12.3 ”W), located in San José de las Lajas municipality, Mayabeque province, Cuba. In the laboratory, samples were kept at 4 °C until processing for nematode extraction. Soil and root samples were processed separately.

Prior to the extraction of nematodes from the soil, the samples were homogenized, fragments of rocks or other elements were discarded and sieved (Retsch® brand sieves, 5 mm). The nematodes were extracted by the Hemminig and Whitehead tray (plate) method, using three replicates of 100 g/accession (9), placing the plates at room temperature. The nematode suspension from each replicate was collected at 72 hours separately and placed in 10 mL vials.

To extract the nematodes present in the roots, these were previously washed with tap water, allowed to air dry on absorbent paper for about 2 hours and the non-functional roots were separated from the functional ones. Functional roots were fractionated into ~ 1 cm portions, homogenized and three sub-samples of 100 g each per accession were obtained and processed by the beating + sieving method (with a set of Retsch® brand sieves with apertures of 300, 125, 63, 45 and 38 μm) (11). The final recovery of each sample was collected on the 38 μm sieve and deposited in 10 mL vials.

Table 1. Characteristics of the carbonate brownish-mellow soil on which the National Collection of *Musa* spp. was established in Cuba between 2015 and 2020

pH		N	MO	P_2O_5	K_2O	Ca^{2+}	Mg^{2+}	Na^+	K^+
KCl	H_2O	(g kg^{-1})		(mg kg^{-1})		(cmol$_c$ kg^{-1})			
6.20	7.00	1.40	17.30	17.50	212.20	27.20	4.10	0.37	0.53

Nematodes extracted from soil and roots, contained in the vials, were heat killed and fixed with TAF (10). Nematode suspensions were quantified using an inverted binocular microscope (Zeiss®), placing the nematode suspension in a PVC counting plate with vertical walls, which has two compartments of different capacity, the nematodes were counted in the larger compartment and when a specimen offered doubts, it was collected with a selector or entomological needle and placed in the smaller compartment to better appreciate the details of its morphology in a Zeiss® optical microscope.

The nematodes were identified, down to genus level, through the observation of the general morphological characters suggested in taxonomic keys (11-13) and the populations were expressed as number of nematodes in 100 g of soil or roots.

To analyze the parameters of the nematode community, the values of absolute frequency (AF), relative frequency (RF), absolute density (AD), relative density (RD), absolute prominence value (APV) and relative prominence value (RPV) were determined (14), using the following formulas:

and Pratylenchidae with two genera each. Four genera of nematodes associated with the rhizosphere of *Musa* spp. were reported in this study for the first time in Cuba (Table 3).

Five of the phytonematode genera found in this study were reported earlier (21), who identified *Radopholus*, *Pratylenchus*, *Helicotylenchus*, *Rotylenchulus* and *Meloidogyne* associated with *Musa* spp. in Cuba.

The genus with the highest relative importance in soil samples, based on geographic distribution (AF and RF), population level (AD and RD) and prominence value (susceptibility of the genotype to the phytonematode) was *Helicotylenchus*. In roots, the genus *Meloidogyne* reached higher values of AF and RF, followed by *Rotylenchulus*, suggesting its wide distribution in the studied area; while, *Helicotylenchus* had higher values of AD, RD, APV and RPV, followed by *Meloidogyne*. (Table 4).

The results indicate that *Helicotylenchus* and *Meloidogyne* were the most distributed and important genera in the selected accessions, which suggests that they will be the most relevant in the cultivar plantations, an aspect to be corroborated in subsequent studies.

$$\text{AF}=\frac{\text{Number of samples with presence of the nematode genus}}{\text{Total samples evaluated}}\ x\ 100$$

$$\text{RF}=\frac{\text{Absolute frequency of nematode genus}}{\sum\text{Absolute frequency of all nematode genera found}}\ x\ 100$$

$$\text{AD}=\text{Mean population of a nematode genus}$$

$$\text{RD}=\frac{\text{Absolute density of nematode genus}}{\sum\text{Absolute density of all nematode genera found}}\ x\ 100$$

$$\text{APV}=\text{absolute density x}\sqrt{\text{absolute frequency}}$$

$$\text{RPV}=\frac{\text{Absolute prominence value}}{\sum\text{Prominence value of all nematodes found}}\ x\ 100$$

Data related to genus, number of individuals (expressed in number of nematodes 100 g^{-1} of soil and roots) and accessions were entered into Excel spreadsheets for statistical analysis. Subsequently, they were processed with the program Infostat version 2022 on Windows 10 (15), through principal component and canonical discriminant analysis, with the objective of determining the relationship between the phytonematode genera and the genomic groups represented in the selected accessions.

RESULTS AND DISCUSSION

Fifteen genera of nematodes belonging to 11 families of two orders were found associated with the selected accessions of *Musa* spp. that were conserved in the national germplasm collection of INIVIT in the period 2015-2020. The Order Rhabditida was the best represented, as 93.3 % of the genera found belonged to it. The most represented family was Hoplolaimidae with four genera, followed by Telotylenchidae

The wide distribution of *Meloidogyne* (95.45 %) in roots was favored by the use of cultivars with partial resistance to *R. similis* (22), which could explain the decreases in the populations of this last species of nematode in Cuban soils. In this regard, some authors reported (21), a decade ago, that the introduction of FHIA hybrids produced important changes in the fauna of nematodes associated to banana and plantain crops, due to the manifestation of partial resistance to *R. similis*, particularly in FHIA hybrids and the variety SH-3436. The entry to Cuba of diseases such as Panama disease (*Fusarium oxysporum* f. sp. cubense ((E.F. Sm.) W.C. Snyder & H.N. Hansen) and black Sigatoka (*Mycosphaerella fijiensis* Morelet) caused variations in the varietal structure of *Musa*, which produced changes in the relative importance of phytonematode species associated to this crop (3, 21).

The genus *Helicotylenchus* reached, in root samples, the highest values of absolute, relative density, absolute and relative prominence, which was related to high populations in the accession 'Manzano Vietnamita', suggesting the possible susceptibility of the genotype to this genus of nematodes,

Table 2. Selected accessions in *Musa* spp. National Collection (2015-2020) in Cuba, for study of associated nematodes, their location and referred behavior against these pest organisms

No	Accessions	Genomic group	Provenance	Primary use	Location			Performance against nematodes	References
					Altitude (m a.s.l)	North	West		
1	'Burro CEMSA'	ABB	Cuba	cooking	47	22.58623	080.22057	RN	8
2	'Manzano Vietnamita'	AAB	Vietnam	dessert	57	22.58614	080.22065		
3	'Pisang Ceilan'	AA	Philippines	dessert	52	22.58567	080.22101		
4	'CEMSA ¾'	AAB	Cuba	cooking	55	22.58649	080.22056	SN	16
5	'INIVIT PV-2011'	AAB	Cuba	cooking	58	22.58721	080.22123		
6	''INIVIT PB-2012'	ABB	Cuba	cooking	57	22.58723	080.22128		
7	'Yangambí'	AAA	Congo	dessert	57	22.58691	080.22072		
8	'Gran Enano'	AAA	Uncertain	dessert	58	22.58675	080.22094	SN	17, 16, 18
9	'Gross Michel'	AAA	Jamaica	dessert	48	22.58722	080.22119	RPP, TR	18
10	'Pisang Jari Buaya'	AA	Malasya	dessert	54	22.58681	080.22133	RR, RH	19
11	'Calcutta 4'	AA	India	wild, inedible fruits	51	22.58663	080.22145	RPR	19
12	'FHIA-18'	AAAB	Honduras	dessert	54	22.58592	080.22136	RR	8, 16, 17
13	'INIVIT PV- 0630''	AAB	Cuba	cooking	59	22.58603	080.22092	SN	17
14	'Enano Guantanamero'	AAB	Cuba	cooking	57	22.58618	080.22092	SN	8, 17
15	'Macho ¾'	AAB	Cuba	cooking	56	22.58661	080.22072	SN	8, 17
16	'FHIA-21'	AAAB	Honduras	cooking	58	22.58634	080.22099	RN, RR	8, 17
17	'SH 3436-L-9'	AAAA	Cuba	dessert	57	22.58611	080.22124	RR	8
18	'FHIA-01'	AAAB	Honduras	Dessert and cooking	56	22.58611	080.22128	RN	8
19	'FHIA 01-V-1' (selección FHIA-23)	AAAA	Honduras	cooking	56	22.58600	080.22130	RR	8, 17
20	'SH 3142'	AA	Honduras	dessert	56	22.58658	080.22149		
21	'SH 3362'	AA	Honduras	dessert	55	22.58654	080.22152		
22	'FHIA-17'	AAAA	Honduras	dessert	54	22.58685	080.22568		

RN: resistance to nematodes; SN: susceptible to nematodes; RPP: partial resistance to *Pratylenchus*; ARR: high resistance to *Radopholus similis* (Cobb) Thorne; RR: resistance to *R. similis*, RPR: partial resistance to *R. similis*, TR: tolerant to *R. similis*, RH: resistant to *Helicotylenchus*

Table 3. Phytonematodes genera associated with selected accessions and conserved at the National Collection of *Musa* spp. in Cuba (period 2015-2020)

Order	Family	Génre	Ref.
Rhabditida Chitwood	Meloidogynidae Skarbilovich	*Meloidogyne* Goeldi	20
	Pratylenchidae Thorne	*Radopholus* (Cobb) Thorne	
		Pratylenchus Filipjev	
	Hoplolaimidae Filipjev	*Helicotylenchus* Steiner	
		Rotylenchulus Linford & Olivera	
		Rotylenchus Filipjev	
		Hoplolaimus von Daday	
	Paratylenchidae Thorne	*Paratylenchus* Micoletzki	
	Tylenchidae Scarbilovich	*Tylenchus* Cobb	
	Telotylenchidae Siddiqi	*Tylenchorhynchus* Cobb	
		Telotylenchus Siddiqi*	
	Belonolaimidae Whitehead	*Belonolaimus* Steiner*	
	Dolichodoridae Chitwood	*Dolichodorus* Cobb*	
	Panagrolaimidae Thorne	*Panagrolaimus* Fuch*	
Dorylaimida Pearse	Longidoridae Thorne	*Longidorus* Micoletzky	20

*New reports for Cuba

Table 4. Ecological indexes determined for the nematode communities associated to the selected accessions of the *Musa* spp. germplasm collection (2015-2020)

Nematode genera	Soil						Roots					
	FA	FR	DA	DR	VPA	VPR	FA	FR	DA	DR	VPA	VPR
Helicotylenchus	**98.48**	**21.96**	**77.97**	**72.58**	**773.77**	**76.15**	63.64	14.95	**304.82**	**56.66**	**2431.61**	**53.34**
Pratylenchus	56.06	12.50	1.95	1.82	14.63	1.44	69.70	16.37	19.98	3.72	166.84	3.66
Radopholus	74.24	16.55	7.03	6.54	60.58	5.96	93.94	22.06	40.24	7.48	390.04	8.56
Meloidogyne	9.09	2.03	1.29	1.20	3.88	0.38	**95.45**	**22.42**	135.83	25.25	1327.10	29.11
Tylenchorhynchus	89.39	19.93	14.95	13.32	141.39	13.92	3.03	0.71	0.06	0.01	0.11	0.00
Tylenchus	37.88	8.45	1.59	1.48	9.79	0.96	10.61	2.49	3.06	0.57	9.97	0.22
Rotylenchus	22.73	5.07	1.33	1.24	6.36	0.63	12.12	2.85	10.27	1.91	35.77	0.78
Paratylenchus	36.36	8.11	0.74	0.69	4.48	0.44	3.03	0.71	0.91	0.17	1.58	0.03
Rotylenchulus	6.06	1.35	0.27	0.25	0.67	0.07	**74.24**	**17.44**	22.76	4.23	196.09	4.30
Dolichodorus	1.52	0.34	0.02	0.01	0.02	0.002	-	-	-	-	-	-
Belonolaimus	6.06	1.35	0.06	0.06	0.15	0.02	-	-	-	-	-	-
Hoplolaimus	4.55	1.01	0.15	0.14	0.32	0.03	-	-	-	-	-	-
Longidorus	1.52	0.34	0.02	0.01	0.02	0.002	-	-	-	-	-	-
Telotylenchus	3.03	0.68	0.03	0.03	0.05	0.005	-	-	-	-	-	-
Panagrolaimus	1.52	0.34	0.02	0.01	0.02	0.002	-	-	-	-	-	-

FA: Absolute Frequency, FR: Relative Frequency, DA: Absolute Density,
DR: Relative Density, VPA: Absolute Prominence Value, VPR: Relative Prominence Value

which has endoparasitic habit in some cultivars of bananas and plantains (21), aspect that should be object of future researches. Another element that could have been related to the presence of high populations of *Helicotylenchus* in the soil and roots was the fact that the predominant weed in the area occupied by this accession was *Echinochloa colona* (L.) Link, also reported as host of *Helicotylenchus* in Cuba (23). This weed species was associated to 100 % of the accessions evaluated in the INIVIT collection (24), an aspect that could have contributed to the maintenance and increase of the populations of this nematode. This is one of the reasons why farmers insist on the need to manage weed hosts of pests in this crop.

The results in this study coincide with those reported in our continent. In this regard, it was found that in *Musa* spp. production areas in Latin America, the nematodes with the greatest relative importance in roots were, in order, *Meloidogyne*, *Helicotylenchus*, Radopholus, *Pratylenchus* and *Rotylenchulus*; while in rhizospheric soil, they were *Helicotylenchus*, *Meloidogyne*, *Rotylenchulus* and *Radopholus* (25, 26). A study developed in Colombia evidenced that, the genera with greater relative importance in roots of musaceae, based on the geographic distribution (AF), population level (AD) and prominence value (susceptibility of the crop to the phytonematode) were *Meloidogyne* and *Helicotylenchus* and, with intermediate importance, *Radopholus*, *Pratylenchus* and *Rotylenchulus* (25).

The presence of *Helicotylenchus multicinctus* (Cobb) Golden and species of the genus *Meloidogyne* together with *R. similis* result in greater damage than that caused by *R. similis* alone (27). Hence the importance given to the permanence of species of both genera in *Musa* spp. plantations, together with *R. similis* nematode which, at one time, was the most important pest of this crop in Cuba and the world.

Knowing the possibilities of genetic improvement by hybridization of certain plants, for 40 years studies have been carried out in different countries with the initial objective of obtaining banana cultivars resistant and/or tolerant to agricultural pests. Crosses of *Musa acuminata* (Colla) with *Musa balbisiana* (Colla) gave rise to genotypes with different genomic groups (28). In Cuba, through the genetic improvement program, cultivars of different genomic groups were obtained which, together with others coming from the Honduran Federation of Agricultural Research (FHIA), conform the varietal structure in the country. For this reason, there is currently a mosaic of cultivars in banana and plantain production in the country, and it is of interest to determine the possible relationship of nematode genera with the different genomic groups.

The nine nematode genera present in roots were not associated with the 22 selected accessions. In the genotypes represented by genomic group ABB, nine phytonematode genera were identified, followed by groups AAB (eight) and AAA (six), with differences in relation to groups AA, AAAA and AAAB in each of which five genera were identified. The highest populations of *Meloidogyne* and *Helicotylenchus* were recorded in accessions belonging to groups AAA and AAB (Figure 1).

In these genomic groups, the most important cultivars for agriculture in Cuba are represented (8) and are the most affected by phytoparasitic nematodes. This type of information should be socialized with farmers, researchers and other social actors linked to banana and plantain crops, as well as with the personnel in charge of the custody of INIVIT's germplasm collection.

The genotypes conformed by genomic groups AAA and AAAB were the most preferred for nematodes of the genus Meloidogyne; whereas, the accessions whose genomic group is AAB were preferred by Helicotylenchus.

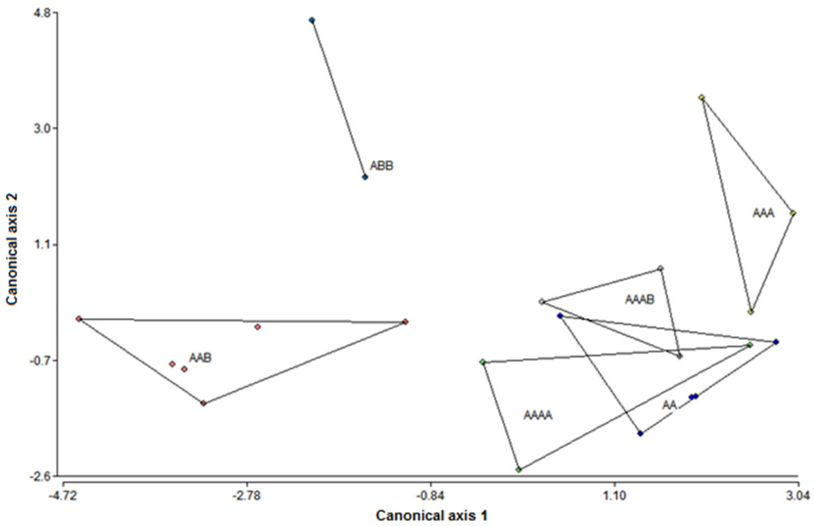

Figure 1. Population of plant-parasitic nematodes estimated in 100 g of roots and their relationship with the genomic groups contained in the germplasm collection of *Musa* spp. in Cuba (2015-2020)

The remaining genomic groups (AA, ABB and AAAA) did not reflect relationships with any specific genus, although they were parasitized, to a lesser extent, by the different genera found in roots (Figure 2).

In this study, the lowest populations of *R. similis* occurred in genotypes 'FHIA-21' (AAAB) and 'FHIA-01-V1' ('FHIA-23') (AAAA), which is in agreement with what some authors reported about the resistance of both genotypes to this nematode (19). The preference of nematodes for cultivars of a given genomic group is, evidently, related to the characteristics of the cultivar beyond its group. Thus, for example, in relation to galls nematodes, it was reported that, in areas of India, *Meloidogyne* spp. had a wide distribution in the cultivar "Nendran" belonging to the AAB group (29); whereas, in plantations of cv. 'Valery' (AAA), in Los Ríos province (Ecuador), it was of greater preference for *Helicotylenchus* and *Radopholus* (30).

In the future, further research should be carried out to determine the resistance/susceptibility of the most widely used cultivars in agriculture and of important accessions for the *Musa* spp. breeding program in Cuba to populations of *Meloidogyne* (as obligate root parasite) and *Helicotylenchus* (also reported as root endoparasite).

From the known sources of resistance, the diploid AA genome appeared predominantly, followed by the triploids AAA and AAB, and several cultivars were used to confirm resistance to different nematode species. Resistant genotypes were 41 % diploid AA, 23 % triploid AAA, 15 % tetraploid AABB, 14 % triploid AAB, 5 % were AAAB and 3 % diploid AB (18).

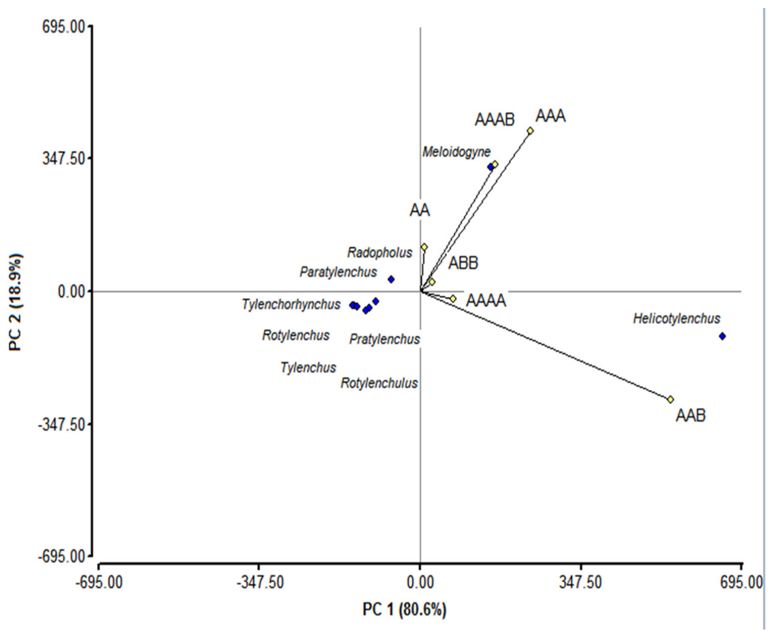

Figure 2. Nematode genera and estimated population in 100 g of roots and their relationship with the genomic groups contained in the germplasm collection of *Musa* spp. (2015-2020)

The results of this study coincide with those observed in field conditions in the country (31, 32), where *Helicotylenchus* and *Meloidogyne* are the most important genera associated to most of the cultivars representing diverse genomic groups of *Musa* spp., ratifying the importance of undertaking studies where the population densities of these nematodes and the possible losses they cause in field conditions are related.

The study of phytonematodes associated with accessions of importance for the breeding program or commercial use, will offer elements to specialists to evaluate/establish IMN measures that contribute to the reduction of populations and the impact of these pests once the collection is established in new areas of INIVIT.

CONCLUSIONS

- Nine genera of nematodes were identified in the roots of *Musa* spp. accessions, and *Meloidogyne* was dominant and widely distributed in the accessions evaluated, ratifying the importance of this genus as a pest of bananas and plantains in Cuba, an aspect to be taken into account by farmers.
- Genotypes with genomic groups AAA and AAAB showed a greater association with *Meloidogyne*, suggesting a possible susceptibility of these genotypes to species of this genus of nematodes, corroborating the importance of undertaking studies where the population densities of nematodes and possible losses are related, offering additional elements for the IMN in the country.

ACKNOWLEDGE

The collective of authors would like to thank the international project "Microbial Uptakes for Sustainable management of major banana pests and diseases (MUSA)" H2020-SFS-2016-2017, Proposal Number 727624 (2017-2021), whose funding made possible the execution of the experiments described in this paper. At INIVIT to Dr. Sergio Rodríguez (EPD), for his unconditional support from the beginning of the work, to José de la C. Ventura Martín, Alfredo Morales Rodríguez, Milagros Basail Pérez, Agustín Adel Vázquez Camejo and Dionelkis Hernández Hernández, as well as at CENSA to Giselle Calabuche Gómez, Dairys García Perera, Lidia López Perdomo and Fraimaris de Moya Abich, for all the help provided during sample processing in the laboratory. Authors thank the reviewers of the manuscript for their valuable suggestions, which contributed to the improvement of the article.

BIBLIOGRAPHY

1. Aribi MM. Plant gene banks: conservation of genetic resources. En: Al-Khayri JM, Jain SM, Penna S. (eds). Sustainable utilization and conservation of plant genetic diversity. Sustainable Development and Biodiversity (SDEB, volume 35). Singapore. Springer. 2024. pp 753-775. https://doi.org/10.1007/978-981-99-5245-8_22
2. Vézina A. Importancia del acceso a recursos genéticos de *Musa* en América Latina y el Caribe. Recursos Naturales y Ambiente. 2009; 53: 72-80.
3. Rodríguez MG, Peteira B, Ventura-Chávez V, Simó GJ, Martínez B, Arévalo J. Elementos para fortalecer el manejo de picudo negro y nematodos fitoparásitos del banano y plátano (*Musa* spp.) en Cuba. Mayabeque, Cuba. Editorial CENSA. 2023. ISBN: 978-959-7125-46-4 (versión digital).
4. Sikora RA, Coyne D, Hallmann J, Timper P. Plant parasitic nematodes in subtropical and tropical agriculture. 3rd edition. Boston, MA, USA. CABI International. 2018. 852 pp. ISBN 9781786391254.
5. Fernández E, Hernández R, López M, Gandarilla H. Nematodos parásitos del banano y plátano y su control. Manejo y lucha biológica. Boletín Técnico (Cuba). 1998; 4(5):1-20.
6. Hernández A, Pérez J, Bosch M, Castro D. Nueva versión de clasificación genética de los suelos de Cuba. Mayabeque, Cuba. Ediciones INCA. 2015. ISBN978-959-7023-77-7.
7. Espinosa-Cuellar A. Factibilidad y beneficios de la inoculación micorrízica arbuscular en la producción de boniato (*Ipomoea batatas* (L.) Lam.). [Tesis doctoral]. Mayabeque, Cuba. Instituto Nacional de Ciencias Agrícolas. 2021. 100 pp.
8. Ministerio de la Agricultura (MINAG) de la República de Cuba. Instructivo Técnico para la producción de *Musa*. Instituto de Investigaciones de Viandas Tropicales. Asociación Cubana de Técnicos Agrícolas y Forestales (ACTAF). Biblioteca ACTAF. Cuba. 2018. 36 pp.
9. Coyne DL, Nicol JM, Claudius-Cole B. Practical plant nematology: a field and laboratory guide. 2nd Edition. Cotonou, Benin. SP-IPM Secretariat, International Institute of Tropical Agriculture (IITA). 2014. 88 pp.
10. van Bezooijen J. Methods and techniques for nematology. Wageningen, Holland. 2006. 112 pp.
11. Eisenback JD. Diagnostic characters useful in the identification of the four most common species of root-knot nematodes (*Meloidogyne* spp.). Sasser JN, Carter CC, Barker KR (Eds). An advanced treatise on *Meloidogyne*. Vol I. Biology and Control. Raleigh, North Carolina, USA. North Carolina State University Graphics. 1985. pp. 95-112.
12. Mai WF, Lyon HH. Pictorial key to genera of plant parasitic nematodes. Fourth Edition Revised. Ithaca. Comstock Publ. 1975. 219 pp.
13. Hooper D, Hallmann J, Subbotin SA. Methods for extraction, processing and detection of plant and soil nematodes. Luc M, Sikora RA, Bridge J. (Eds). Plant parasitic nematodes in subtropical and tropical agriculture. 2nd edition. Wallingford, UK. CAB International. 2005. pp. 53-86.
14. Norton DC. Ecology of Plant - Parasitic Nematodes. New York, Chichester, Brisbane, Toronto. Wiley & Sons, Incoporated, John. 1978. 268 pp. ISBN 0-471-03188-7.
15. Di Rienzo JA, Casanoves F, Balzarini MG, González L, Tablada M, Robledo CW. InfoStat versión 2022 Grupo InfoStat, FCA, Universidad Nacional de Córdoba, Argentina. Disponible en: http://www.infostat.com.ar (Consultado: 28 de abril de 2022).

16. Morales L, González J, Rodríguez S, González L, Ventura JC, Filipia R, *et al*. Manejo de clones de bananos y plátanos. LL Vázquez (Ed.). Compendio de buenas prácticas agroecológicas en manejo de plagas. Cuba. Asociación Cubana de Técnicos Agrícolas y Forestales (ACTAF). 2014. Pp. 142-144. ISBN 978-959-7210-84-9
17. Fernández E. Inform to “PROMUSA Nematology working group meeting”. INFOMUSA. 2001; 10 (2): 2-5.
18. Quénéhervé P, Valette C, Topart P, T du Montcel, Salomon F. Nematode resistance in bananas: screening results on some wild and cultivated accessions of *Musa* spp. Rev. Euphytica. 2009; 165:123-136. https://doi.org/10.1007/s10681-008-9773-7 .
19. Sousa ABP, Rocha A, Oliveira W, Rocha L, Amorim EP. Phytoparasitic nematodes of *Musa* spp. with emphasis on sources of genetic resistance: A systematic review. Plants. 2024; 13: 1299. https://doi.org/10.3390/plants13101299
20. Fernández M. Lista de nematodos fitoparásitos de Cuba (Segunda contribución; 122 plantas). Academia de Ciencias de Cuba. Serie Agrícola. 1970; No. 16: 29 pp.
21. Fernández-Gonzálvez E, Gandarilla Bastarrechea H, González J, Draguiche JM, Pérez A, Casanueva-Medina K, *et al.* Nematodos de importancia económica en banano, plátano, tubérculos y raíces comestibles en Cuba. Nematropica. 2015; 45 (2): 31. http://journals.flvc.org/nematropica/issue/view/4193
22. Fernández E, Gandarilla H, Martínez E, Pérez L, Martínez I, Rojas N, *et al*. Fitonematodos de las musáceas en Cuba. Una visión actualizada. Pino O, Rubio A, Rodríguez Y, Rodríguez MG, Alfonso P, Pererea CL, *et al* (Eds.). Memorias del Seminario Internacional de Sanidad Agropecuaria (SISA) (audio libro). Mayabeque, Cuba. 2023. Pág. 22-23. ISBN: 978-959-7125-50-1.
23. Casanueva MK, Fernández GE, Tejeda M, Vidal U, Paredes RE. Malezas hospedantes de fitoparásitos en diferentes zonas productoras de banano y plátano en las provincias de Artemisa y La Habana. Fitosanidad. 2016; 20 (3): 125-129.
24. Ventura Chávez V, Peteira Delgado-Oramas B, González Díaz L, Enríquez Regalado R, Miranda Cabrera I, Rodríguez Hernández MG. Malezas asociadas a accesiones seleccionadas de la colección de germoplasma de *Musa* spp. en Cuba. Rev. Agricultura Tropical. 2024; 10 (1): 40-52.
25. Riascos-Ortiz D, Mosquera-Espinosa A, Varón de Agudelo F, Muñoz-Florez JE. Importancia relativa de nematodos fitoparásitos asociados a *Musa* spp. y las interrelaciones entre los géneros de mayor valor de prominencia. Fitopatología Colombiana. 2021; 45(1): 1-9.
26. Monteiro SDJ, Pereira SJR, Enrique CJ, Marchão LR, Amorim PE, Da Cunha CD. Identification of plant parasitic nematodes in triploid and tetraploid bananas in Brazil. Rev. Caatinga, Mossoró. 2020; 33(4): 865 - 877.
27. Caveness FE, Badra T. Control of *Helicotylenchus multicinctus* and *Meloidogyne javanica* in established plantain and nematode survival as influenced by rainfall. Nematropica. 1980; 10: 10-14.
28. Champions J. El plátano. Técnicas agrícolas y producciones tropicales. La Habana. Instituto Cubano del Libro. 1969. p. 16-32.
29. Ashfak O, Usman A, Rasmi A. Plant parasitic nematodes associated with banana (*Musa* spp. var. ‘Nendran’ AAB) - a diversity analysis at banana fields in Ottappalam Taluk of Kerala, India. Thai Jour. Agricultural Sci. 2021; 54(3): 148-162.
30. Guevara Santana FJ, Miranda Cabrera I, Ceiro Catasú WG, Hidalgo Díaz L, Arévalo Ortega J. Géneros de nematodos parásitos de raíces de banano (*Musa paradisiaca* L.) en la provincia Los Ríos, Ecuador. Rev. Proteccion Veg. 2024; 39: 1-9. https://cu-id.com/2247/v39e16.
31. Pérez-Vicente L, Fernández-Gonzálvez E, Javer-Higgison E. Diseases of banana and plantain in Cuba and Caribbean basin: impact, epidemiology and management. Uma S, Mayil Vaganan M, Agrawal A. (Eds). Bananas and plantains: leading-edge research and development. Vol. 1: Diversity, improvement and protection. Tiruchirappalli, India. ICAR-National Research Centre for Banana. 2020. Pp 537-570.
32. Almarales Antúnez M, Jiménez Carbonell R, Gandarilla Basterrechea H, Castellanos González L. Nematodos en la provincia Cienfuegos, hospedantes y distribución. Nematropica. 2015; 45(2): 46 -47. http://journals.flvc.org/nematropica/issue/view/4193