

RESEARCH/INVESTIGACIÓN

PLANT PARASITIC NEMATODES ASSOCIATED WITH BANANA AND PLANTAIN IN EASTERN AND WESTERN DEMOCRATIC REPUBLIC OF CONGO

M. Kamira^{1,3}, S. Hauser², P. van Asten^{1,2}, D. Coyne², and H. L. Talwana³

¹Consortium for Improving Agricultural-based Livelihoods in Central Africa (CIALCA) Project, Bukavu, Democratic Republic of Congo; ²International Institute of Tropical Agriculture (IITA); ³School of Agricultural Sciences Makerere University, Kampala, Uganda; Corresponding author haltalwana@agric.mak.ac.ug

ABSTRACT

Kamira M., S. Hauser, P. Van Asten, D. Coyne, and H. L. Talwana. 2013. Plant parasitic nematodes associated with banana and plantain in eastern and western Democratic Republic of Congo. *Nematropica* 43:216-225.

Plant-parasitic nematode incidence, population densities and associated damage were determined from 153 smallholder banana and plantain gardens in Bas Congo (9 – 646 meters above sea level, m.a.s.l) and South Kivu (1043 – 2005 m.a.s.l), Democratic Republic of Congo, during 2010. Based on the frequency of total nematode soil and root extraction, *Helicotylenchus multicinctus* (89%), *Meloidogyne* spp. (54%) and *Radopholus similis* (30%) were the most widespread, while *Pratylenchus goodeyi* (18%) *Helicotylenchus dihystra* (18%), *Rotylenchulus reniformis* (14%), and *Pratylenchus* spp. (6%) were localized in occurrence. The occurrence and abundance of the nematode species was influenced by altitude: *R. similis* declined at elevations above 1300 m; *P. goodeyi* declined at elevations below 1200 m; *H. multicinctus* and *Meloidogyne* spp. were found everywhere with higher but non-dominant densities at lower altitudes; *Pratylenchus* spp. was restricted to lower altitudes; while *H. dihystra* and *R. reniformis* were scattered at both low and high altitudes. *Helicotylenchus multicinctus* occurred in higher population densities than other nematode species, especially at the lower elevations. Damage to banana roots (percentage necrotic root tissue) was moderate to high, irrespective of altitude and banana type. To facilitate development of pragmatic plant parasitic nematode management, such baseline studies provide information upon which to enable informed and suitable strategies, such as cultivar selection and distribution.

Key words: D.R. Congo, *Helicotylenchus multicinctus*, *Meloidogyne* spp., *Musa* spp. *Pratylenchus goodeyi*, *Radopholus similis*, root necrosis.

RESUMEN

Kamira M., S. Hauser, P. Van Asten, D. Coyne, and H. L. Talwana. 2013. Nematodos fitoparásitos asociados a los cultivos de banano y plátano en el este y oeste de la República Democrática del Congo. *Nematropica* 43:216-225.

Se determinó la incidencia, densidad de población y el daño asociado a nematodos fitoparásitos en 153 cultivos de plátano y banano de agricultores pequeños en Bas Congo (9 – 646 metros sobre el nivel del mar) y South Kivu (1043 – 2005 m.s.n.m.) en la República Democrática del Congo, en 2010. Basados en frecuencia hallada en extracciones de suelo y raíces, *Helicotylenchus multicinctus* (89%), *Meloidogyne* spp. (54%) y *Radopholus similis* (30%) fueron los nematodos más comunes, mientras que *Pratylenchus goodeyi* (18%) *Helicotylenchus dihystra* (18%), *Rotylenchulus reniformis* (14%), y *Pratylenchus* spp. (6%) se encontraron de manera localizada. La altitud influyó sobre la incidencia y abundancia de las especies: *R. similis* declinó a elevaciones de más de 1300 m; *P. goodeyi* declinó a elevaciones de menos de 1200 m; *H. multicinctus* y *Meloidogyne* spp. se encontraron en todas las altitudes, pero las densidades fueron más altas a baja altitud; *Pratylenchus* spp. sólo se encontró en las altitudes bajas; mientras que *H. dihystra* y *R. reniformis* se encontraron tanto a altitudes bajas como altas. *Helicotylenchus multicinctus* se observó en mayor densidad de población que otras especies, especialmente en las altitudes más bajas. El daño a las raíces de banano (porcentaje de raíces necróticas) fue de moderado a alto, sin importar la altitud o el tipo de banano. Con el fin de facilitar el desarrollo de planes de manejo de nematodos fitoparásitos, estos estudios brindan la información necesaria para escoger estrategias adecuadas tales como la selección y distribución de cultivares.

Palabras clave: Congo, *Helicotylenchus multicinctus*, *Meloidogyne* spp., *Musa* spp., necrosis radical, *Pratylenchus goodeyi*, *Radopholus similis*.

INTRODUCTION

Bananas and plantains (*Musa* spp.) are important crops in the Democratic Republic of Congo (D.R. Congo) (Frison and Sharrock, 1999) produced by smallholder farmers for subsistence and household income and are considered the second most important staple crop after cassava (Bakelana *et al.*, 2000). They are grown across a range of environments and produce fruits year-round, providing a source of energy when other crops are often not available. Plantain (*Musa* AAB), and cooking bananas (*Musa* AAB, *Musa* ABB), East African highland bananas (*Musa* AAA-EA) and dessert banana (*Musa* AAA, *Musa* AA) are some of the banana types grown in D.R. Congo (Swennen *et al.*, 1995). At lower altitudes (below 1200 m above sea level, for example, in Bas Congo western D.R. Congo), plantain and dessert banana are primarily grown, while at mid to high altitudes (1200 to 2000 m.a.s.l.) especially in Eastern Congo, the East African highland banana types dominate (Mobambo, 2003). The Congo basin is also viewed as a secondary centre of plantain diversity and thus important from a biodiversity perspective (Swennen *et al.*, 1995; Daniells *et al.*, 2001). However, the area planted to banana and plantain, and yield per unit area have declined by 20 - 60% (Mobambo *et al.*, 2010) even though demand remains high, raising their market value and often out of the reach of poor urban households (Bakelana *et al.*, 2000).

The reasons for the declining yields include a range of factors, which may depend on site. Pests and diseases, soil fertility, access to water, etc. are among the key constraints regionally, while only limited information is available for D.R. Congo (Dowiya *et al.*, 2009). Due to the long history of banana and plantain cultivation in the D.R. Congo pests and diseases have co-evolved with the crop (Mbida *et al.*, 2001), thus adding a more difficult dimension to the pest and disease problem (Jones, 2000). Plant parasitic nematodes are among the most important constraints to banana and plantain production, globally reported to cause yield losses of between 30 - 60% (Bridge, 2000; Gowen *et al.*, 2005). Although only limited information is available, a brief study previously indicated that damage by plant parasitic nematodes in many of the banana and plantain growing regions of DR Congo is severe (Bakelana *et al.*, 2000). Consequently, nematode species abundance, distribution, and underlying mechanisms (e.g. ecological factors and farming practices) influencing nematode distribution and pathogenicity are unknown. This study reports the incidence, nematode population densities and associated damage of plant-parasitic nematodes on banana and plantain in DR Congo determined during 2010.

MATERIALS AND METHODS

Study site and Sampling

The study was conducted in two provinces of Bas-Congo (western D.R. Congo) and South Kivu (eastern D.R. Congo) (Fig. 1). Two hundred forty one composite banana root and soil samples were collected from 153 randomly selected banana fields; 111 fields within the 9 territories of Bas Congo: Kasangulu (9), Lukula (10), Luozi (13), Madimba (22), Mbanza Ngungu (10), Mwanda (15), Seke Banza (5), Songololo (11) and Tshela (16), located at altitudes ranging between 9 m to 646 m.a.s.l.; and 42 fields within the 2 territories of Walungu (27) and Kabare (15) in the province of South Kivu at altitudes ranging between 1043 m to 2005 m.a.s.l. Among the fields sampled in Bas Congo, 85 fields were grown to a mixture of dessert and plantain bananas, 20 to plantain bananas only and 13 to dessert bananas only. In South Kivu 27 fields were a monoculture of brewing bananas, 5 of cooking bananas while 3 were an intercrop of plantain, brewing and cooking bananas. Where different banana cultivars existed, each cultivar was sampled separately. The samples were collected following a procedure described by Speijer and De Waele (1997), a hole of 20 x 20 x 20 cm was made adjacent to the corm of the banana plant and the banana roots and soil were collected and placed in a labeled plastic bag. Samples were taken from 5 to 8 randomly selected individual plants per field, pooled to form a composite root and soil sample, stored in a cool box and transported to the laboratory within 48 hours of collection.

Root Necrosis Assessment, Nematode Extraction And Processing

Root cortical necrosis (percentage) in banana roots was evaluated on five functional roots randomly selected per sample. The selected roots were cut to about 10 cm length, each root piece sliced lengthwise and necrosis in the exposed cortical tissue scored as percentage, each root piece contributing a maximum score of 20% and for the five root pieces selected from the sample a total score of 100% (Speijer and De Waele, 1997). The root pieces assessed for necrosis were washed with tap water, surface dried, chopped into ~2 cm segments and thoroughly mixed before removing a 10 g fresh weight sample. The 10 g sub-sample was covered with water to just submerge the roots and the sample was macerated in a kitchen blender for 10 - 15 seconds. Nematodes from roots were extracted for 24 - 36 hours using the modified Baermann funnel technique (Coyne *et al.*, 2007). Nematodes were also extracted from 100 cm³ of soil using a modified Baermann funnel technique. The extracted nematode suspensions were decanted into a beaker, allowed to settle for 2 hours

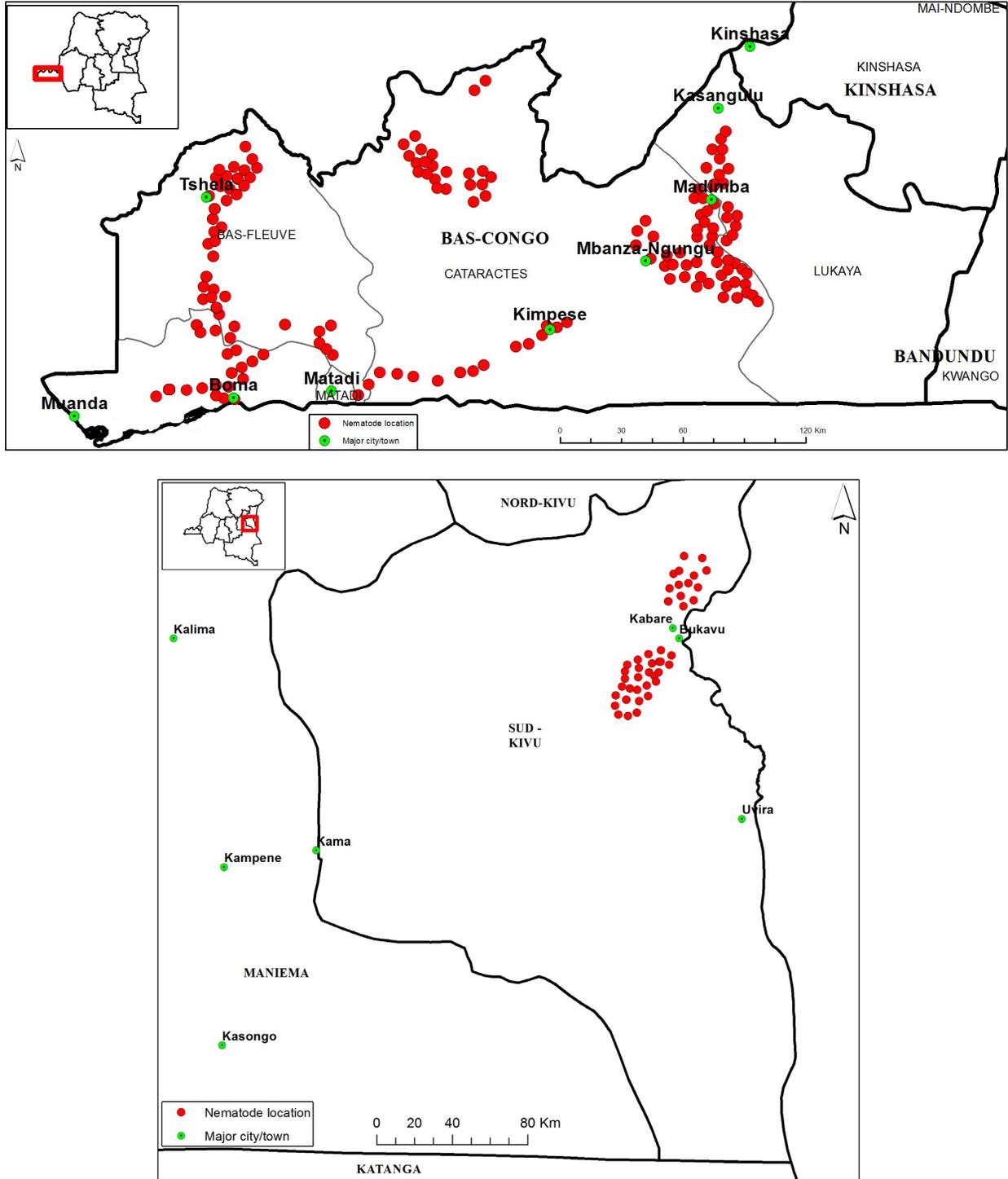


Fig. 1: Map of Bas Congo (above) and South Kivu (below) showing the sampling points for the survey.

and reduced to 25 ml by gently decanting off the excess water. Vermiform nematodes (male, females and juveniles) were identified to species level using morphometric parameters and individuals counted from 2 ml aliquots drawn from 25 ml suspension with a compound microscope with under-stage lighting. Where no adults existed, nematodes were identified to genus level only. For sedentary endoparasitic *Meloidogyne* spp. and *Rotylenchulus* spp. only vermiform males and second-stage juveniles were recorded. After counting, the nematodes were heat relaxed, fixed in formalin (Coyle *et al.*, 2007) and sent to the Nematology unit of the South Africa Plant Protection Research Institute Biosystematics division for confirmation of our preliminary identification.

Data Analysis

Nematode densities were calculated per 100 g of root fresh weight or 100 cm³ of soil. The frequency of occurrence for each species identified was calculated for each of the 11 territories. A species was considered widespread when it appeared in more than 30% of the fields (Adiko, 1988). Mean population densities were calculated for each species observed, and the maximum density recorded for each banana type within a territory. A species with a mean density of over 10 individuals per 100 g of roots was considered abundant (Adiko, 1988). As the occurrence of banana and plantain cultivar types generally depended on geographical location, no qualitative or quantitative comparisons were possible between Bas Congo and South Kivu territories. A Chi-squared test was conducted on nematode frequency data within each respective province to determine significance of differences among banana types. Necrosis damage observations, expressed as percentages, were normalized using angular transformation prior to analysis of variance. Correlations were calculated among nematode densities, root necrosis damage and altitude.

RESULTS

Seven plant parasitic nematode species: *Helicotylenchus dihystra*, *H. multincinctus*, *Meloidogyne* spp., *Pratylenchus goodeyi*, *Pratylenchus* spp., *Radopholus similis* and *Rotylenchulus reniformis* were recovered from roots and soil of bananas and plantains in eastern and western D.R. Congo. The most frequently occurring plant parasitic nematodes were *H. multincinctus* and *Meloidogyne* spp. *Helicotylenchus multincinctus* was found in 89.4% of all sampled fields, but the frequency of occurrence was higher in fields at the lower altitudes (98.5% in Bas Congo) than in fields at higher altitudes (48% in South Kivu). *Meloidogyne* spp. were recorded in 54% of all the sampled fields with 48% of fields in Bas Congo and 61% of fields

in South Kivu infested (Table 1). *Pratylenchus goodeyi* was found exclusively at higher elevations, i.e. Kabare and Walungu in South Kivu. Overall, the frequency of nematode species occurrence in roots and soil samples ranged from 6% (*Pratylenchus* spp.) to 89.4% (*Helicotylenchus multincinctus*) (Table 1).

Helicotylenchus multincinctus also occurred in higher population densities than other nematode species in Bas Congo. Particularly high population densities of *H. multincinctus* were recovered in Lukula, Luozi, Madimba Mbanza Ngungu and Mwanda. Meanwhile, high *Meloidogyne* spp. population densities were found in Madimba and their lowest density recorded in Songololo (Tables 2 - 3). High *R. similis* population densities were found in Kasangulu, Luozi, Madimba and Mwanda. Of particular note is the relatively high population density of *R. reniformis* in Luozi territory, and *Pratylenchus* spp. in Madimba territory. *Pratylenchus goodeyi* was abundant and the predominant nematode species in South Kivu (Tables 2 - 3). Generally, the dominant nematode species varied with altitude but not with banana type (i.e. brewing, cooking, dessert or plantain). *Radopholus similis* was restricted to lower altitudes (<1,200 m), highest densities being recovered at lower altitudes. *Pratylenchus goodeyi* was the dominant species at higher altitudes (>1,200 m). *Helicotylenchus multincinctus* and *Meloidogyne* spp. were found at all altitudes with higher but not dominant densities at lower altitudes (Table 4).

Necrosis observed in roots was moderate to high, for example, the lowest and highest percentage score on plantain was 18% and 59% at Mbanza Ngungu and Kabare, respectively (Table 5), but it was not significantly different among banana types. Root necrosis was positively and significantly correlated to population densities of *H. multincinctus* ($r = 0.23$, $P \leq 0.001$), *P. goodeyi* ($r = 0.41$, $P < 0.002$) and *R. similis* ($r = 0.14$, $P = 0.017$).

DISCUSSION

All the seven plant parasitic nematode species recovered from banana and plantain in this study are potentially damaging. The abundance and prevalence of, and damage associated with *H. multincinctus* on banana in the current study is contrary to previous studies that indicate *R. similis* and *P. goodeyi* as the most prevalent and damaging nematodes on banana in the African great lakes region and only regard *H. multincinctus* as a constraint where environmental conditions, i.e., altitude, temperature and rainfall are sub-optimal for both the banana crop and *R. similis* (Gichure and Ondieki, 1977; Bridge, 1988; Sikora *et al.*, 1988; Sarah, 1989; Kshaija *et al.*, 1994; Elsen *et al.*, 2000; Gaidashova *et al.*, 2009). However, it supports an observation by Speijer and Fogain (1999) that *H. multincinctus* is the most common nematode

Table 1. Frequency of occurrence (percentage) of plant parasitic nematodes in roots and soil of bananas in two provinces of Democratic Republic of Congo.

Province/ Territory	Number of fields sampled	Altitude range (m.a.s.l.)	<i>Helicotylenchus dihystera</i>	<i>H. multincinctus</i>	<i>Meloidogyne spp.</i>	<i>Pratylenchus goodeyi</i>	<i>Pratylenchus spp.</i>	<i>Radopholus similis</i>	<i>Roylenchulus reniformis</i>
Bas Congo									
Kasangulu	9	512 – 631	35.7	100.0	53.6	-	7.1	71.4	21.4
Lukula	10	107 – 199	32.4	100.0	67.6	-	0.0	41.2	26.5
Luozi	13	196 – 409	15.2	95.7	37.0	-	0.0	10.9	26.1
Madimba	22	563 – 646	16.3	100.0	51.3	-	7.5	53.8	20.0
Mbanza Ngungu	10	564 – 643	23.5	100.0	61.8	-	0.0	32.4	5.9
Mwanda	15	9 – 272	0.0	92.9	48.2	-	1.8	21.4	1.8
Seke Banza	5	370 – 444	14.3	100.0	57.1	-	14.3	57.1	0.0
Songololo	11	178 – 454	15.8	100.0	13.2	-	34.2	26.3	21.1
Tshela	16	144 – 330	9.7	98.4	77.4	-	1.6	12.9	22.6
South Kivu									
Kabare	15	1485 – 1705	20.6	41.2	47.1	100.0	-	-	2.9
Walungu	27	1043 – 2005	16.7	55.0	75.0	100.0	-	-	0.0
Overall	153		18.2	89.4	53.6	18.2	6.0	29.8	13.5

Table 2. Maximum (and mean) nematode population densities per 100 g root fresh weight of bananas in two provinces of Democratic Republic of Congo.

Province/ Territory	<i>Helicotylenchus dhystera</i>	<i>H. multicinctus</i>	<i>Meloidogyne</i> spp.	<i>Pratylenchus goodeyi</i>	<i>Pratylenchus</i> spp.	<i>Radopholus similis</i>	<i>Rotylenchulus reniformis</i>
Bas Congo							
Kasangulu	572 (108)	59,813 (20,873)	1,250 (411)	-	24,375 (1,741)	69,000 (10,866)	25 (3)
Lukula	1,009 (169)	119,643 (35,587)	11,814 (2,845)	-	-	8,195 (1,358)	15,517 (1,710)
Luozi	207 (19)	156,750 (28,992)	6,875 (625)	-	-	44,250 (2,609)	41,125 (2,100)
Madimba	381 (26)	170,363 (21,308)	258,250 (6,506)	-	43,000 (1,075)	43,625 (5,247)	70 (5)
Mbanza Ngungu	207 (21)	153,365 (19,355)	4,000 (765)	-	-	36,875 (3,566)	35 (2)
Mwanda	-	263,500 (56,484)	52,500 (3,971)	-	-	14,625 (1,044)	-
Seke Banza	93 (13)	76,875 (19,843)	4,750 (1,429)	-	250 (36)	1,875 (559)	-
Songololo	210 (15)	25,832 (4,966)	600 (46)	-	21,216 (1,800)	4,077 (346)	3,120 (205)
Tshela	820 (81)	81,328 (8,220)	4,950 (966)	-	-	11,482 (1,041)	13,934 (1,281)
South Kivu							
Kabare	120 (10)	8,880 (1366)	4,400 (636)	149,700 (63,246)	-	-	12 (1)
Walungu	77 (5)	4,410 (660)	3,750 (414)	270,380 (26,218)	-	-	-

Table 3. Maximum (and mean) nematode population densities in 100 cm³ soil of bananas in two provinces of Democratic Republic of Congo.

Province/ Territory	<i>Helicotylenchus dhystera</i>	<i>H. multicinctus</i>	<i>Meloidogyne</i> spp.	<i>Pratylenchus goodeyi</i>	<i>Pratylenchus</i> spp.	<i>Radopholus similis</i>	<i>Rotylenchulus reniformis</i>
Bas Congo							
Kasangulu	48 (8)	575 (219)	365 (121)	-	25 (2)	174 (42)	49 (5)
Lukula	85 (9)	526 (184)	124 (39)	-	-	348 (52)	32 (5)
Luozi	47 (4)	969 (199)	172 (30)	-	-	16 (1)	391 (33)
Madimba	33 (2)	2,426 (234)	781 (141)	-	163 (7)	106 (18)	17 (2)
Mbanza Ngungu	54 (7)	2,686 (456)	401 (102)	-	-	105 (16)	20 (1)
Mwanda	-	942 (223)	44 (15)	-	117 (5)	120 (10)	38 (2)
Seke Banza	29 (4)	884 (252)	34 (12)	-	6 (1)	17 (6)	-
Songololo	12 (1)	886 (129)	129 (7)	-	459 (80)	75 (9)	244 (22)
Tshela	11 (1)	644 (121)	128 (28)	-	12 (1)	131 (9)	190 (15)
South Kivu							
Kabare	13 (2)	121 (17)	180 (20)	866 (244)	-	-	-
Walungu	20 (2)	120 (16)	199 (41)	300 (95)	-	-	-

Table 4. Influence of altitude on nematode species occurrence and population density on banana in Democratic Republic of Congo.

Altitude ranges (m.a.s.l.)	Nematode population density (per 100 g root fresh weight)						
	<i>Helicotylenchus dihystera</i>	<i>Helicotylenchus multicinctus</i>	<i>Meloidogyne</i> spp.	<i>Pratylenchus</i> spp.	<i>Pratylenchus goodeyi</i>	<i>Radopholus similis</i>	<i>Rotylenchulus reniformis</i>
> 2000	39	1,132	0	0	45,775	0	0
1601 - 2000	2	842	430	0	49,260	0	4
1201 - 1600	14	1,579	488	0	52,611	0	0
801 - 1200	1	246	749	586	0	0	0
401 - 800	862	20,830	3,568	862	0	5,262	7
0 - 400	53	26,509	1,773	288	0	1,346	1,087

Table 5. Nematode damage (root necrosis) and nematode population densities (per 100 g root fresh weight) of banana cultivars sampled in two provinces of Democratic Republic of Congo.

Province/ Territory	Banana type	Root necrosis [Mean + s.e]		Nematode population densities (per 100 g root fresh weight)						
		<i>Helicotylenchus dihystera</i>	<i>Helicotylenchus multicinctus</i>	<i>Meloidogyne</i> spp.	<i>Pratylenchus goodeyi</i>	<i>Pratylenchus</i> spp.	<i>Radopholus similis</i>	<i>Rotylenchulus reniformis</i>		
Bas Congo										
Kasangulu	Dessert	42.0 + 8.1	63	17,374	-	339	-	3,482	13,929	-
Lukula		38.9 + 7.6	59	29,306	-	3,307	-	-	2,324	1,694
Luozi		31.2 + 6.4	40	26,722	-	807	-	-	4,909	4,381
Madimba		20.1 + 4.4	26	22,937	-	10,370	-	1,792	2,109	7
Mbanza Ngungu		26.6 + 7.6	42	37,400	-	531	-	-	7,016	-
Mwanda		23.8 + 6.2	-	55,394	-	2,979	-	-	1,285	-
Seke Banza		21.3 + 12.3	31	13,634	-	292	-	-	625	-
Songololo		19.8 + 7.1	-	3,300	-	30	-	809	217	73
Tshela		21.1 + 5.5	68	5,915	-	831	-	-	344	2,196
Kasangulu	Plantain	26.4 + 8.1	154	24,372	-	482	-	-	7,804	7
Lukula		37.1 + 7.1	267	41,171	-	2,435	-	-	499	1,724
Luozi		34.6 + 6.2	-	31,073	-	458	-	-	500	8
Madimba		38.1 + 5.3	25	18,864	-	710	-	-	9,953	2
Mbanza Ngungu		17.8 + 7.1	3	3,315	-	972	-	-	500	4
Mwanda		34.0 + 5.7	-	51,419	-	4,821	-	-	838	-
Seke Banza		30.0 + 10.7	-	24,499	-	2,281	-	63	510	-
Songololo		35.5 + 6.8	28	6,465	-	60	-	2,692	462	324
Tshela		22.2 + 5.3	94	10,381	-	1,092	-	-	1,695	424
South Kivu										
Kabare	Brewing	47.5 + 6.4	16	2,112	-	724	58,955	-	-	1
	Cooking	53.5 + 15.1	-	-	-	125	132,750	-	-	-
	Dessert	23.0 + 15.1	-	-	-	515	2,730	-	-	-
	Plantain	59.0 + 15.1	10	-	-	785	77,865	-	-	-
	Dessert	35.8 + 10.7	-	275	-	1,303	68,240	-	-	-
	Brewing	39.9 + 5.3	8	883	-	114	22,529	-	-	-
	Cooking	36.4 + 9.6	-	150	-	424	29,152	-	-	-
	Plantain	24.6 + 9.6	2	766	-	656	1,472	-	-	-

species in roots of *Musa* or *Ensete* in Africa. The magnitude of necrosis associated to *H. multicinctus* observed in the current study may be a result of either the high populations recovered or a shift in the “known” reproductive fitness and pathogenicity of *H. multicinctus*, since histopathological observations of *H. multicinctus*-infected roots showed superficial lesions that do not extend into the stele of banana roots (Zuckerman and Strich-Harari, 1963). It is apparent that this damage could translate into heavy yield losses, because elsewhere where *H. multicinctus* was found as the dominant species on banana, it caused significant crop losses, for example on plantain in western Africa (Badra and Caveness, 1983; Sarah, 1985).

The prevalence and abundance of the other nematode species; namely, *Meloidogyne* spp., *R. similis* and *P. goodeyi* was typical of what is reported in the region. *Meloidogyne* spp. was encountered in 54% of the fields sampled distributed throughout the two provinces, with higher populations recovered at lower to mid altitudes, for example, in Madimba. *Radopholus similis* was encountered in 30% of the fields with its highest density recovered at mid-altitudes, in Kasangulu. This distribution of *R. similis* reflects its tropical (thermophilic) nature, and supports other reports, such as Bridge (1988) in Tanzania and Kashaija *et al.* (1994) in Uganda. *Pratylenchus goodeyi* was abundant at elevations above 1200 m.a.s.l. in South Kivu, confirming similar observations by Sarah (1989), Kashaija *et al.* (1994), Price and Bridge (1995), Bridge *et al.* (1997), Fogain (1998), Price (2000), and Gaidashova *et al.* (2009). The high *P. goodeyi* population densities and frequencies in the territories of Walungu and Kabare are most likely enhanced by the lengthy banana monoculture (Speijer and Fogain 1999), but their distribution and density is related to altitude and are similar to reports elsewhere (Elsen *et al.*, 2000; Fogain, 2001; Talwana *et al.*, 2003; Gaidashova *et al.*, 2009).

Helicotylenchus dihystra and *R. reniformis* appeared to have a scattered distribution at both low and high altitudes. *Pratylenchus* spp., however, had a clustered but erratic distribution at lower altitudes (9 m to 646 m.a.s.l.) within Bas Congo province, with highest frequency and mean population density in Songololo. It is likely that this species might indeed be *P. coffeae*, given its previous recovery from bananas in Bas Congo (Vangu, 2005), including from cv. Yangambi Km 5 (‘Kinsiesi’) a cultivar viewed to be tolerant to the nematode (Speijer and De Waele, 1997). Alternatively, it may be a morphologically similar species, such as *P. speijeri*, which was recently described (De Luca *et al.*, 2012), after first being identified as *P. coffeae* occurring on plantain in Ghana (Brentu *et al.*, 2004). *Pratylenchus coffeae* has been increasingly reported from plantain and banana in West and Central Africa

(Speijer and Fogain, 1999; Sarah, 1989; Bridge *et al.*, 1995; Coyne, 2009). This nematode is highly pathogenic and a potentially serious threat to banana and plantain production (Bridge *et al.*, 1997; Speijer *et al.*, 2001; Brentu *et al.*, 2004; Coyne and Dubois, 2011).

The observed high root necrosis together with the low nematode densities recovered in soil samples indicates that farmers are suffering substantial losses due to nematodes, which are undoubtedly being spread using contaminated suckers for planting material, a practice common in many smallholder banana growing areas (Tenkouano *et al.*, 2006). This also shows the relatively high susceptibility and sensitivity to plant parasitic nematodes of the banana cultivars grown by the farmers in D.R. Congo.

In conclusion, the results of this survey revealed the significant prevalence of *Helicotylenchus multicinctus*, *Meloidogyne* spp., *Pratylenchus goodeyi* and *Radopholus similis*, the four most important nematodes on banana. These species are known to cause severe damage and yield losses throughout most banana growing areas in the tropical and subtropical regions of the world and their distribution is very closely linked to altitude and temperature. However, the current study is not exhaustive but provides baseline information upon which further studies can extend the investigations, for example, partitioning and quantifying damage caused to banana by individual nematode species and, prioritizing and guiding development of management strategies.

ACKNOWLEDGEMENT

We gratefully acknowledge the financial support from the European Union through the International Institute of Tropical Agriculture (IITA) to the Agriculture and Forestry Research (REAFOR) project in D.R. Congo of which this study was part.

LITERATURE CITED

- Adiko, A. 1988. Plant parasitic nematodes associated with plantain, *Musa paradisiaca* (AAB) in Ivory Coast. *Revue de Nematologie* 1:109 – 113.
- Anonymous. 1997. Monographie de la province du SUD-KIVU, Republique Democratique du Congo - Mars 1997.
- Badra, T. and F. E. Caveness. 1983. Effects of dosage sequence on the efficacy of non-fumigant nematicides, plantain yields, and nematode seasonal fluctuations as influenced by rainfall. *Journal of Nematology* 15:496 – 502.
- Bakelana, B. K., P. Vangu and K. K. Mputu. 2000. Results of a survey on banana conducted among farmers in the Democratic Republic of Congo. *Infomusa* 9:22 – 23.
- Brentu, F. C., Speijer, P. R., Green, K. R., Hemeng,

- B. M. S., De Waele, D., and Coyne, D. L. 2004. Microplot evaluation of the yield reduction potential of *Pratylenchus coffeae*, *Helicotylenchus multicinctus* and *Meloidogyne javanica* on plantain cv. Apantu-pa (*Musa* spp., AAB-group) in Ghana. *Nematology* 6: 455-462.
- Bridge, J. 1988. Plant nematode pests of banana in East Africa with particular reference to Tanzania. Pp 35-39 in Proceedings of a workshop "Nematodes and borer Weevil in Bananas: Present status of research and outlook", Bujumbura, Burundi, 7 – 11 December 1987. INIBAP, Montpellier.
- Bridge, J. 2000. Nematodes of bananas and plantains in Africa: research trends and management strategies relating to small-scale farmer. *Acta Horticulturae* 540:391 – 408.
- Bridge, J., R. Fogain, and P. R. Speijer. 1997. The root lesion nematodes of bananas: *Pratylenchus coffeae* (Zimmermann, 1898) Filip. and Schu. Stek., 1941, *Pratylenchus goodeyi* Sher & Allen, 1953. *Musa* Pest Fact Sheet No. 2. INIBAP, Montpellier, France.
- Bridge, J., N. S. Price, and P. Kofi. 1995. Plant parasitic nematodes of plantain and other crops in Cameroon, West Africa. *Fundamental and Applied Nematology* 18:251 – 260.
- Coyne, D. 2009. Pre-empting plant-parasitic nematode losses on banana in Africa: which species do we target?. *Acta Horticulturae* 828:227 – 236.
- Coyne, D. L., J. M. Nicol, and B. Claudius-Cole. 2007. Practical Plant Nematology: A field and laboratory guide. SP-IPM Secretariat, International Institute of Tropical Agriculture (IITA), Cotonou, Benin.
- Daniells, J., C. Jenny, D. Karamura, and K. Tomekpe. 2001. Musalogue: a catalogue of *Musa* germplasm. Diversity in the genus *Musa* (E. Arnaud and S. Sharrock, compil.). International Network for the Improvement of Banana and Plantain (INIBAP), Montpellier, France.
- De Luca, F., Troccoli, A., Duncan, L. W., Subbotin, S. A., Waeyenberge, L., Coyne, D. L., Brentu, F. C. and Inserra, R. N. 2012. *Pratylenchus speijeri* n. sp., a new root-lesion nematode pest of plantain in West Africa. *Nematology* 14: 987-1004
- Dowiya, N. B., C. L. Rweyemamu, and A. P. Maerere. 2009. Banana (*Musa* spp.) cropping systems, production constraints and cultivar preferences in eastern Democratic Republic of Congo. *Journal of Animal and Plant Sciences* 4:341 – 356.
- Elsen, A., P. R. Speijer, R. Swennen, and D. De Waele. 2000. Nematode species densities, root damage and yield of bananas (*Musa* spp.) in Uganda. *African Plant Protection* 6:31 – 36.
- Fogain, R. 1998. Study of tolerance/resistance of *Musa* to nematodes. Banana Improvement Project No. 18 Final Report.
- Fogain, R. 2001. Nematodes and weevil of bananas and plantains in Cameroon: occurrence, importance and host susceptibility. *International Journal of Pest Management* 47:201 – 205.
- Frison, E. A. and S. L. Sharrock. 1999. The economic, social and nutritional importance of banana in the world. Pp 21–35 in Picq C., E. Fouré, and E. A. Frison (eds). Bananas and Food Security. International Symposium, Douala, Cameroon, 10–14 November, 1998. Montpellier, France: INIBAP.
- Gaidashova, Svetlana V., P. van Asten, D. De Waele, and B. Delvaux. 2009. Relationship between soil properties, crop management, plant growth and vigour, nematode occurrence and root damage in East African Highland banana-cropping systems: a case study in Rwanda. *Nematology* 11:883 – 894.
- Gichure, E. and J. J. Ondieki. 1977. A survey of banana nematodes in Kenya. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* 84:724 – 728.
- Gowen, S. R., R. Fogain, and P. Quénéhervé. 2005. Nematode parasites of bananas, plantains and abaca. Pp 431 – 460 in Luc, M., R.A. Sikora, and J. Bridge (eds). Plant- Parasitic Nematodes in Subtropical and Tropical Agriculture (2nd Edition). C.A.B. International, Wallingford, UK.
- Jones, D. R. (ed.). 2000. Diseases of Banana, Abacá and Enset. CABI Publishing. Wallingford, United Kingdom.
- Kashaija, I. N., P. R. Speijer, C. S. Gold and S. R. Gowen. 1994. Occurrence, distribution and abundance of plant parasitic nematodes of bananas in Uganda. *African Crop Science Journal* 2:99 – 104.
- Mbida C., H. Doutrelepont, L. Vrydaghs, R. Swennen, H. Beekman, E. De Langhe, and P. de Maret. 2001. First archaeological evidence of banana cultivation in central Africa during the third millennium before present. *Vegetation History and Archaeobotany* 10:1–6.
- McSorley, R. and J. L. Parrado. 1986. Nematological review: *Helicotylenchus multicinctus* on bananas – an international problem. *Nematologica* 16:73-91.
- Mobambo, K. N. 2003. Stratégies de développement de la production bananière par l'introduction et la distribution des meilleures variétés en RD Congo à soumettre pour financement au fonds commun pour les produits de base. Groupe Intergouvernemental sur la Banane et sur les Fruits Tropicaux, Puerto de la Cruz (ESP), Rome (ITA), Pp 7.
- Mobambo, P., C. Staver, S. Hauser, B. Dheda and G. Vangu. 2010. An innovation capacity analysis to identify strategies for improving plantain and banana (*Musa* spp.) productivity and value addition in the Democratic Republic of Congo. *Acta Horticulturae* 879:821 – 827.

- Price, N. S. 2000. The biogeography of the banana nematodes *Radopholus similis* and *Pratylenchus goodeyi*. *Acta Horticulturae* 540:431 – 440.
- Price, N. S. and J. Bridge. 1995. *Pratylenchus goodeyi* (Nematoda: Pratylenchidae) a plant parasitic nematode from the montane highlands of Africa. *Journal of African Zoology* 109:435 – 442.
- Sarah, J. L. 1985. Les nematodes des bananiers plantains en Cote-d'Ivoire. Pp. 88-93 in *La Cooperation Internationale pour une Recherche Efficace sur le Plantain et les Bananes*. Abidjan, Ivory Coast. INIBAP Montpellier, France.
- Sarah, J. L. 1989. Banana nematodes and their control in Africa. *Nematropica* 19:199-216.
- Speijer, P. R. and D. De Waele. 1997. Screening of *Musa* germplasm for resistance and tolerance to nematodes, INIBAP Technical Guidelines 1, International Network for the Improvement of Banana and Plantain, INIBAP Montpellier, France, pp 47.
- Speijer, P. R. and R. Fogain. 1999. *Musa* and *Ensete* nematode pest status in selected African countries. Pp. 99-108 in Frison E.A., C.S. Gold, E.B. Karamura, and R.A. Sikora, (eds). *Mobilizing IPM for Sustainable Banana Production in Africa*. INIBAP, Montpellier, France.
- Speijer, P. R., M. O. Rotimi, and D. De Waele. 2001. Plant parasitic nematodes associated with plantain (*Musa* spp., AAB-group) in Southeastern Nigeria and their relative importance compared to other biotic constraints. *Nematology* 3:423 – 436.
- Swennen, R., D. Vuylsteke and R. Ortiz. 1995. Phenotypic Diversity and Patterns of Variation in West and Central African Plantains (*Musa* spp., AAB Group Musaceae). *Economic Botany* 49:320 – 327.
- Talwana, H. A. L., P. R. Speijer, C. S. Gold, R. L. Swennen, and D. De Waele. 2003. A comparison of the effect of nematodes *Radopholus similis* and *Pratylenchus goodeyi* on growth, root health and yield of the East Africa cooking banana (*Musa* AAA-group). *International Journal of Pest management* 49:199-204.
- Tenkouano, A., S. Hauser, D. L. Coyne, and O. Coulibaly. 2006. Clean Planting Materials and Management Practices for Sustained Production of Banana and Plantain in Africa. *Chronica Horticulturae* 46:14-18.
- Vangu, P. G. 2005. Action du vetiver (*Vetiveria zizanioides*) dans la protection du bananier (*Musa* sp.) contre les attaques des nematodes des racines. Mémoire, inedit, UNIKIN/ R.D.C.
- Zuckerman, B. M. and D. Strich-Harari. 1963. The life stages of *Helicotylenchus multicinctus* (Cobb) in banana roots. *Nematropica* 9:347-353.

Received:

2/XI/2012

Accepted for publication:

29/V/2013

Recibido:

Aceptado para publicación: