SPATIAL DISTRIBUTION OF NEMATODE POPULATION DENSITIES AND NEMATODE DAMAGE IN ROOTS OF THREE BANANA CULTIVARS IN UGANDA

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ABSTRACT

Talwana, H. A. L., P. R. Speijer, and D. De Waele. 2000. Spatial distribution of nematode population densities and nematode damage in roots of three banana cultivars in Uganda. Nematropica 30:19-31.

The spatial distribution of nematode populations and damage in roots of Nabusa (*Musa* AAA-group 'Matooke'), Pisang Awak (*Musa* ABB) and Sukali Ndizi (*Musa* AB) three banana cultivars widely grown in Uganda, was investigated at three locations, each with a distinctive nematode population and composition. At Namulonge, central Uganda, where *Radopholus similis* was the dominant nematode species, and at Ntungamo, southwestern Uganda, where *Pratylenchus goodeyi* was the dominant species, suckers were removed from established mats and assessed for nematode reproduction and damage. At Namulonge, Ntungamo, and Mbarara, southwestern Uganda, where *R. similis* and *P. goodeyi* coexist, suckers removed three months after planting were assessed for nematode reproduction and damage. Nematode population density distribution along the primary roots was observed to be random for both plant types of the three cultivars at all locations. An exception was recorded for three-month-old sucker-derived plants of all three cultivars at Mbarara, where higher *P. goodeyi* densities were recorded closer to the corm. Nematode densities in primary roots, secondary roots, and root tips were generally not significantly different for both plant types of a single cultivar except for three month old sucker-derived Pisang Awak plants at Ntungamo where higher *Meloidogyne* spp. densities were observed in the root tips. Consistently, nematode damage (root necrosis) was higher ($P < 0.05$) close to the corm than further along the primary roots, regardless of cultivar and location.

Key words: East African highland bananas, *Helicotylenchus multicinctus*, *Meloidogyne* spp., nematode damage, *Pratylenchus goodeyi*, *Radopholus similis*, root necrosis, spatial distribution.

RESUMEN

Talwana, H. A. L., P. R. Speijer y D. De Waele. 2000. Distribución espacial de las densidades de nematodos y daño a raíces en tres variedades de banano en Uganda. Nematrópica 30:19-31.

La distribución espacial de poblaciones de nematodos y el daño a las raíces en tres variedades de banano en Uganda; Nabusa (*Musa* AAA-grupo 'Matooke'), Pisang Awak (*Musa* ABB) y Sukali Ndizi (*Musa* AB), fueron investigadas en tres localidades, cada una con una población y composición de nematodo distintiva. En Namulonge, Uganda central, donde *Radopholus similis* fue la especie de nematodo dominante, y en Ntungamo, suroeste de Uganda, donde lo fue *Pratylenchus goodeyi*, los hijos de plantaciones establecidas, fueron removidos y evaluados en cuanto a reproducción y daño de nematodo. En Namulonge, Ntungamo, y Mbarara, suroeste de Uganda, donde *R. similis* and *P. goodeyi* coexisten, los vástagos removidos tres meses después del plantío, también fueron evaluados para reproducción y daño de nematodos. La distribución de la densidad poblacional de nematodo a lo largo de las raíces primarias fue al azar, para ambos tipos de plantas, en las tres variedades y en todas las localidades. Una excepción se reportó con las plantas derivadas de los hijos de tres meses, en las tres variedades, en Mbarara, donde las mayores densidades de *P. goodeyi* fueron reportadas cerca del bulbo. Las densidades de nematodos en las raíces primarias, secundarias y en las puntas, generalmente no fueron diferentes para ambos tipos de plantas en una misma variedad, con la excepción de las plantas de Pisang Awak, derivadas de hijos de tres meses, en Ntungamo, donde las mayores den-

sidades poblacionales de *Meloidogyne* spp., fueron observadas en las puntas de la raíz. En forma consistente, el daño de los nematodos (necrosis de la raíz), fue significativamente mayor ($P < 0.05$) cerca del bulbo que más hacia las raíces primarias, independientemente de la variedad y la localización.

Palabras claves: bananos del altiplano de Africa del este, daño de nematodo, distribución espacial, *Helicotylenchus multicinctus*, *Meloidogyne* spp., necrosis radical, *Pratylenchus goodeyi*, *Radopholus similis*.

INTRODUCTION

Uganda is Africa's leading producer and consumer of bananas with a daily per capita consumption ranging from 2.0 to 4.5 kg (Rubaihayo and Gold, 1993). Eighty-five percent of the bananas grown in Uganda are East African highland bananas (*Musa* spp. AAA-group); the other bananas belong mainly to either the AB or ABB genome groups (Karamura and Karamura, 1994). Pisang Awak (local name: Kayinja), a brewing banana, is a commonly grown representative of the ABB-group in Uganda while a commonly grown representative of the AB-group is the dessert banana Sukali Ndizi (Karamura and Karamura, 1994). They are grown between elevations 890 to 2 400 m. (Speijer *et al.*, 1994).

Banana production in Uganda has shown a steady decline per unit land area during recent years (Rubaihayo and Gold, 1993). The major constraints to banana production in Uganda are pests, particularly weevils and nematodes (Gold *et al.*, 1993; Speijer *et al.*, 1994), diseases, especially Black Sigatoka leaf spot (Vuylsteke and Swennen, 1988), declining soil fertility and frequent droughts (Karamura, 1993). Plant parasitic nematodes have only recently been recognized as serious pests of East African highland bananas (Bridge, 1988; Sarah, 1989; Kashaija *et al.*, 1994) and there are many questions about their precise role in declining banana productivity. Nematode infection of root tissues is known to impair absorption and transportation of water and nutrients and to weaken plant anchorage. Nematode damage to bananas is associated with a reduction in bunch weight, loss of bunches due to plant toppling, increase in crop cycle duration and decrease in plantation longevity (Gowen and Quénéhervé, 1990). Nematode related yield losses in East African highland bananas may range from 30% (Speijer *et al.*, 1999a) to 50% (Speijer and Kajumba, 1996).

The most important and widespread plant parasitic nematode species in Uganda are *Radopholus similis* Cobb, *Pratylenchus goodeyi* Sher and Allen, *Helicotylenchus multicinctus* (Cobb) Golden and *Meloidogyne* spp. (Bridge, 1988; Kashaija *et al.*, 1994). Their distributions are influenced by altitude, with *R. similis* being dominant at lower altitudes (<1 400 m) and *P. goodeyi* being the dominant species at higher altitudes (>1 400 m). *Helicotylenchus multicinctus* and *Meloidogyne* spp. are found at all altitudes although there may be higher population densities of these nematodes at lower altitudes (Elsen *et al.*, 1998; Speijer *et al.*, 1994).

It is likely that nematode damage to the base of the primary roots causes the greatest damage to the plant, because this would affect the entire root. Little is known about nematode distribution and feeding within the rhizosphere. Where exactly in the root system do nematodes feed? Is there a difference in nematode population growth in different root parts and is that difference cultivar dependent? Do the differences in root development observed among *Musa* genotypes (Swennen *et al.*, 1986) affect nematode repro-

duction and their feeding? Necrosis may be observed at the root base, along the primary roots and on the secondary roots. The site of infection may vary with nematode species but generally, different species may be found in a single root (Gowen and Quénéhervé, 1990).

The objective of the present study was to investigate the spatial distribution of the different nematode species and the damage they cause in three banana cultivars widely grown in Uganda; Nabusa, Pisang Awak and Sukali Ndizi, representing AAA- (East African highland), ABB-, and AB- groups, respectively. Nabusa (AAA-EA) is one of the commonly grown cultivars in Uganda for cooking purposes, Pisang Awak is popular among farmers for manufacture of beer, and Sukali Ndizi is the most widely grown dessert banana (Karamura and Karamura, 1994) and there are differences in host response of these cultivars to *R. similis* and *H. multicinctus* infection in controlled experiments and in farmers' fields in Uganda (Speijer *et al.*, 1999b, Elsen *et al.*, 1998). When information on the spatial nematode distribution and damage is available, an understanding may be had about the role of nematodes in production loss in East African highland bananas at the root system level and may lead to the development of alternative methods for nematode damage assessment and control.

MATERIALS AND METHODS

The study was conducted at three locations in Uganda: a) Namulonge, central Uganda, altitude of 1 150 m; b) Ntungamo, southwestern Uganda, altitude of 1 450 m; and c) Mbarara, southwestern Uganda, altitude of 1 330 m. In Namulonge, *R. similis* is the most abundant species while *P. goodeyi* is the predominant species in Ntungamo. In Mbarara, *R. similis* and *P. goodeyi* occur together. Three *Musa* cultivars belonging to three genome groups were included in the study: Nabusa (East African highland AAA-group), Pisang Awak (ABB-group) and Sukali Ndizi (AB-group). Two experiments were conducted. In the first experiment, sword suckers detached from established mats were examined, while in the second experiment, three month old sucker derived plants were examined.

Evaluation of sword suckers of established mats. The experiment was conducted at Namulonge and Ntungamo. The trial sampled at Namulonge was established in June 1994 to assess the production loss caused by nematodes on three different banana cultivars of Nabusa, Pisang Awak, and Sukali Ndizi and the extent of damage on the different cultivars. All planting material was pared, selected for absence of weevil damage and disinfected for 20 minutes in hot water at 53°C to 55°C (Colbran 1967). The material was then planted in polyethylene bags, with one half of the plants infested with 93 g of banana root segments containing approximately 16 368 *P. goodeyi*, 6 603 *R. similis* and 83 421 *H. multicinctus* and the other half not infested. Plants were left in the polyethylene bags for one month to allow for effective infestation of the material. Prior to planting, a 50 g soil sample (at a depth of 15 cm) was collected per plot and thoroughly mixed to produce one composite soil sample, from which the nematode densities were established. The soil samples contained 25 *H. multicinctus*, 8 *H. dyhistera*, and 8 *Scutelonema bradys*. A randomized complete block design with a factorial arrangement of treatments was used. The trial consisted of six treatments, 2 nematode treatments (infested and non-infested) and three cultivars, with a plot size of 36 mats and plant spacing of 3 m × 3 m. Each treatment was replicated six times. Cow manure was added to each hole at planting. Constant mulching using a mixture of grasses cut from adjacent fields

under fallow or maize stalks when available, and trapping for weevils (*Cosmopolites sordidus*) were done in all the plots.

Sampling for the present study was done during June 1997 when Nabusa, Pisang Awak and Sukali Ndizi were in the 4th, 5th and 6th ratoons, respectively. In the farmer's field at Ntungamo, the mats were naturally infested with nematodes, the plantation was about 15 years old and mats were sampled during October, 1996.

Per cultivar, roots of ten, 70 to 100-cm high suckers of mats in a flowering stage were removed from the soil and assessed for nematode densities and root damage. At flowering, the root system of the mother plant is in a state of decline due to natural senescence and root pathogen activity but the root system of the daughter plant (sucker) is increasing and may be of benefit during this critical phase by providing additional anchorage to the mother plant and also as a supplementary source of nutrients (Lavigne, 1987). Because of the difficulty in removing all roots without damaging them, the number of roots removed per sucker ranged from 5 to 25 roots per plant. However, the total number of roots collected per cultivar were 261, 385 and 555 from Nabusa, Pisang Awak and Sukali Ndizi plants, respectively, giving 210, 353 and 549 root samples, respectively, on which nematode damage and nematode populations were assessed. At Ntungamo, 10 roots per sucker were removed giving 71, 35 and 37 samples of Nabusa, Pisang Awak and Sukali Ndizi, respectively.

Evaluation of 3 months old sucker derived plants. The experiment was conducted at all three locations. Hot water treated sword suckers of relatively uniform size of Nabusa, Pisang Awak and Sukali Ndizi were acclimatized for one month in plastic bags before they were planted in the field. At the time of planting in the field the plants were inoculated by placing 100 g of nematode infected banana root segments (a mixture of Nabusa, Pisang Awak and Sukali Ndizi root pieces collected during paring of suckers) around each plant. At Namulonge, the nematode infected root segments applied per plant contained a mixture of approximately 27 300 *R. similis*, 7 000 *H. multicinctus* and 1 000 *Meloidogyne* spp. At Ntungamo, the inoculum consisted of approximately 12 000 *P. goodeyi*, 2 400 *H. multicinctus* and 400 *Meloidogyne* spp. while at Mbarara, the inoculum consisted of 43 650 *P. goodeyi*, 1 500 *R. similis* and 16 330 *Meloidogyne* spp.

A completely randomized design was used with two replicates, each replicate consisting of five plants per cultivar. Three months after planting, the roots of ten suckers of each cultivar were removed from the soil and assessed for nematode densities and root damage. At Namulonge a total of 86, 98 and 199 roots of Nabusa, Pisang Awak and Sukali Ndizi, respectively, were collected giving 73, 35 and 159 samples, respectively, on which nematode damage and populations were assessed. At Ntungamo, 131, 120 and 123 roots of Nabusa, Pisang Awak and Sukali Ndizi, respectively, were collected giving 53, 52 and 43 samples, respectively. At Mbarara, 44, 49 and 50 roots of Nabusa, Pisang Awak and Sukali Ndizi, respectively, were collected giving 35, 35 and 37 samples, respectively.

Assessment of nematode density and damage distribution. Nematode density and damage were assessed according to the procedures described by Speijer and De Waele (1997). Root damage was assessed in each whole root excavated by determining the percentage root necrosis of 20-cm-long root segments collected starting from the proximal end of the root (end attached to the corm) then proceeding outwards towards the distal end, as well as a 20-cm-long root segment collected from each distal end of the root (root tip). For each plant, root segments collected at equal distances from

the corm or from the root tips were pooled. The pooled root samples were labeled according to the distance from the corm as 20, 40, 60, 80, etc. Secondary roots were collected from sword suckers detached from established mats in Namulonge and Ntungamo. In three-month-old sucker derived plants, secondary roots were only collected in Namulonge because assessment at Ntungamo and Mbarara occurred during dry weather when it was not possible to recover secondary roots due to soil compaction. Secondary roots were collected from the entire root length and pooled. The pooled root segments previously scored for root damage, and secondary roots were chopped into approximately 0.5 cm pieces, thoroughly mixed and a 5-g sub-sample taken from which nematodes were extracted by a modified Baermann funnel (Hooper, 1990) after maceration in an electric blender. Extraction time was 16-20 hours at room temperature of approximately 24°C. The nematodes were then identified to species and counted. Nematode counts are presented as numbers of nematodes per 100-g fresh root weight. Nematode numbers consisted of adult females and males plus juveniles, except for *Meloidogyne* spp., for which only second stage juveniles and males are reported.

Statistical analysis. Nematode numbers were transformed to log (x + 1) before they were subjected to analysis of variance (ANOVA) using the Generalized Linear Models (GLM) procedure of SAS (SAS Institute 1989). Correlation coefficients (Pearson's) between nematode counts, root damage and distance from corm (i.e., 20, 40, 60, 80 cm, etc. from the corm) were calculated according to the correlation procedure of SAS (SAS Institute 1989). The correlation between nematode counts and distance from the corm provided evidence of the nematode population distribution pattern along the root length.

RESULTS

Radopholus similis was present at Namulonge and *P. goodeyi* at Ntungamo, whereas at Mbarara, both *R. similis* and *P. goodeyi* were detected. *Helicotylenchus multicinctus* and *Meloidogyne* spp. were found at all three locations.

At Namulonge, *R. similis* population densities were apparently lower in primary roots of suckers detached from established mats than in primary roots of three-month-old sucker derived plants (Table 1). An opposite relationship was observed for *H. multicinctus*. In three-month-old sucker derived plants, *R. similis* population densities in primary roots were lower ($P < 0.05$) in Nabusa and Pisang Awak compared to Sukali Ndizi, while the opposite trend was observed for population densities in sword suckers detached from established mats. In sword suckers detached from established mats, population densities of *H. multicinctus* were higher ($P < 0.05$) in all Nabusa root parts examined (primary, secondary and root tips) than in the corresponding root parts of Pisang Awak and Sukali Ndizi. Such a trend was not observed for the *H. multicinctus* population densities in the various root parts of three-month-old sucker derived plants. Population densities of *Meloidogyne* spp. did not differ significantly for sword suckers detached from established mats among the root parts of each respective cultivar and among cultivars for each respective root part. Densities were very low for three-month-old sucker derived plants, with the exception of high densities in secondary roots of Sukali Ndizi. Generally at Namulonge, nematode numbers were higher in primary roots and root tips than in secondary roots but these differences not significant ($P > 0.05$) for any of the cultivars or plant types. Nematode numbers in primary root segments were not correlated with the distance from

Table 1. Spatial distribution of nematode population densities in roots of suckers detached from established mats and three-month-old sucker derived plants at Namulonge, Uganda

Cultivar/Trial	Nematode population densities in different root parts[x,y]			Correlation coefficients[z]	
	Primary roots	Secondary roots	Root tips	Nematode numbers and distance from corm	Nematode numbers and necrosis
Suckers detached from established mats					
Radopholus similis					
Nabusa	2 698	980	2 882	0.02	-0.02
Pisang Awak	3 260	282	2 740	-0.05	-0.10
Sukali Ndizi	1 817	278	1 971	-0.10	0.23*
Helicotylenchus multicinctus					
Nabusa	7 574 b	5 036 b	3 471 b	0.09	0.18
Pisang Awak	872 a	282 a	648 a	0.05	0.05
Sukali Ndizi	2 034 a	317 a	896 a	0.05	-0.05
Meloidogyne spp.					
Nabusa	189	231	472	-0.03	-0.14
Pisang Awak	1 011	705	1 189	-0.09	0.07
Sukali Ndizi	722	500	452	0.13*	-0.10
Three-month-old sucker derived plants					
Radopholus similis					
Nabusa	3 868 a	833 a	1 756	-0.03	-0.11
Pisang Awak	3 960 a	24 740 b	3 175	0.09	-0.22
Sukali Ndizi	4 517 b	1 499 a	920	-0.18	-0.11
Helicotylenchus multicinctus					
Nabusa	1 581	0	1 136	0.02	-0.08
Pisang Awak	601	0	287	-0.08	0.20
Sukali Ndizi	1 495	83	682	0.00	0.19
Meloidogyne spp.					
Nabusa	257	0 a	53	-0.14*	-0.11
Pisang Awak	49	0 a	0	0.03	0.11
Sukali Ndizi	99	13 911 b	610	0.14	0.08

[x]Means followed by same letter are not significantly different at $P < 0.05$ according to least square difference of the mean method.
[y]Nematode numbers per 100 g fresh root weight.
[z]* = correlation coefficients significant at $P < 0.05$.

the corm for either plant type except for *Meloidogyne* spp. in sword suckers detached from established Sukali Ndizi mats (r = 0.13, $P < 0.05$) and three-month-old sucker derived Nabusa plants (r = -0.14, $P < 0.05$) (Table 1). Additionally, nematode numbers and necrosis were not correlated for any of the plant types and cultivars, except for *R. similis* in sword suckers detached from established Sukali Ndizi mats (r = 0.23, $P < 0.05$) (Table 1). However, root necrosis decreased ($P < 0.01$) with increasing distance from the corm in all three cultivars for both plant types (Table 4).

At Ntungamo, *P. goodeyi* population densities were apparently higher in all root parts examined from suckers detached from established mats than from those examined in three-month-old sucker derived plants (Table 2). In sword suckers detached from established mats, population densities of *P. goodeyi* did not differ significantly between the three cultivars. *Helicotylenchus multicinctus* population density in primary roots of Nabusa averaged about 2 000 per 100 g fresh root weight but was not observed in roots of Pisang Awak and Sukali Ndizi. Significantly ($P < 0.05$) higher population densities of *Meloidogyne* spp. were present in primary roots of Pisang Awak and in root tips of Pisang Awak and Sukali Ndizi than in the corresponding root parts of Nabusa. Populations of *P. goodeyi* (but not populations of *H. multicinctus* or *Meloidogyne* spp.) were significantly different among locations in the roots, being higher in the primary roots than either root tips or secondary roots for Nabusa and Sukali Ndizi. In Pisang Awak roots, however, the numbers of *P. goodeyi* were significantly higher in the secondary roots than either primary roots or root tips. In three-month-old sucker derived plants, *P. goodeyi* population densities also did not differ significantly between the three cultivars. Mean population densities of *H. multicinctus* did not exceed 20 per 100 g fresh root weight in any of the three cultivars. Nabusa primary roots supported the highest *Meloidogyne* spp. population densities, followed by Pisang Awak primary roots, while population densities on Sukali Ndizi averaged less than 100 nematodes per 100 g fresh root weight. Root tips of Pisang Awak supported the highest *Meloidogyne* spp. population densities, followed by Nabusa root tips. No *Meloidogyne* spp. were extracted from Sukali Ndizi root tips at Ntungamo (Table 2). The numbers of *P. goodeyi* were significantly different in root pieces of Pisang Awak at Ntungamo. Nematode numbers in root segments and distance from the corm, and nematode numbers in root segments and necrosis were not correlated in either experiment. Root necrosis decreased with increasing distance from the corm in sword suckers detached from established mats of the three cultivars ($P < 0.01$) and in only Pisang Awak in three-month-old sucker derived plants ($P < 0.05$) (Table 4).

At Mbarara, *Meloidogyne* spp. were, in general, the most abundant. Higher population densities were extracted from primary roots and root tips of Nabusa than from Pisang Awak and Sukali Ndizi. *Radopholus similis* was observed in low population densities in roots of Nabusa and Sukali Ndizi while it was not observed in roots of Pisang Awak. *Helicotylenchus multicinctus* was not observed in roots of Nabusa and Pisang Awak while low population densities (3 per 100-g fresh roots) were observed in primary roots of Sukali Ndizi (Table 3). *Pratylenchus goodeyi* numbers decreased ($P < 0.05$) with increasing distance from the corm in all three cultivars. *Radopholus similis* numbers decreased ($P < 0.05$) with increasing distance from the corm in Nabusa (Table 3). Root necrosis decreased ($P < 0.01$) with increasing distance from the corm in all three cultivars (Table 4).

Table 2. Spatial distribution of nematode population densities and nematode damage in roots of suckers detached from established mats and three-month-old sucker derived plants at Ntungamo, Uganda.

Cultivar/Trial	Nematode population densities in different root parts[y]			Correlation coefficients[z]	
	Primary roots	Secondary roots	Root tips	Nematode numbers and distance from corm	Nematode numbers and necrosis
Suckers detached from established mats					
Helicotylenchus multicinctus					
Nabusa	2 138	0	729	-0.14	0.49
Pisang Awak	0	0	0	—	—
Sukali Ndizi	0	0	0	—	—
Meloidogyne spp.					
Nabusa	0	0	333	0.51	-0.20
Pisang Awak	4 337	0	5 414	0.18	-0.17
Sukali Ndizi	227	0	2 166	0.07	-0.22
Pratylenchus goodeyi					
Nabusa	10 662	1 603	2 312	-0.43	0.16
Pisang Awak	6 767	26 573	6 662	0.35	-0.20
Sukali Ndizi	11 064	0	2 832	0.44	-0.16
Three-month-old sucker derived plants					
Helicotylenchus multicinctus					
Nabusa	0	—	20	0.19	—
Pisang Awak	5	—	4	-0.07	-0.02
Sukali Ndizi	8	—	0	-0.15	0.05
Meloidogyne spp.					
Nabusa	4289	—	4 681	-0.05	-0.05
Pisang Awak	2278	—	14 808	0.25*	-0.28
Sukali Ndizi	95	—	0	0.26	0.04
Pratylenchus goodeyi					
Nabusa	2566	—	1 226	-0.03	-0.14
Pisang Awak	1187	—	4 847	0.10	-0.06
Sukali Ndizi	1261	—	603	-0.14	-0.17

[y]Nematode numbers per 100 g fresh root weight; secondary roots were not recovered from detached suckers because assessment was done in relatively dry weather.
[z]* = correlation coefficients significant at $P < 0.05$.

Table 3. Spatial distribution of nematode population densities and nematode damage in roots of suckers removed three months after planting (three-month-old sucker derived plants) at Mbarara, Uganda.

Cultivar	Nematode population densities in different root parts[x,y]		Correlation coefficients[z]	
	Primary roots	Root tips	Nematode numbers and distance from corm	Nematode numbers and necrosis
Radopholus similis				
Nabusa	817	6	-0.22*	0.33**
Pisang Awak	0	0	—	—
Sukali Ndizi	64	21	-0.15	-0.08
Helicotylenchus multicinctus				
Nabusa	0	0	—	—
Pisang Awak	0	0	—	—
Sukali Ndizi	3	0	—	—
Meloidogyne spp.				
Nabusa	9 014	4 802 a	0.16	-0.27*
Pisang Awak	5 090	15 596 b	-0.15	0.14
Sukali Ndizi	7 126	3 432 a	0.18	-0.05
Pratylenchus goodeyi				
Nabusa	808	119	-0.38**	0.30*
Pisang Awak	1737	93	-0.48**	0.23*
Sukali Ndizi	679	163	-0.40*	0.10

[x]Means followed by same letter are not significantly different at $P < 0.05$ according to least square difference of the mean method.
[y]Nematode numbers per 100 g fresh root weight.
[z]*, **, = Correlation coefficients significant at $P < 0.05$ or $P < 0.01$, respectively.

DISCUSSION

One interpretation of the apparently random nematode distribution along the primary roots is that nematode species complete their life cycles within root tissues with little or no migration from points of initial infection to new healthy tissues. If so, then several nematode generations might pass and large colonies develop at the point of initial root infection rather than spreading along the root. Nematode densities in both suckers detached from established mats and three-month-old sucker derived plants suggest that these nematode species generally penetrate the primary root equally over the total root length independently of the banana cultivar. This was, however, not the case for *P. goodeyi* at Mbarara in the three-month-old sucker derived plants. Generally nematode densities increased equally in the root tips and the primary and secondary roots, except for three-month-old sucker derived

Table 4. Nematode damage (percentage root necrosis) distribution in roots of suckers detached from established mats at Namulonge and Ntungamo, and three-month-old sucker derived plants at Namulonge, Ntungamo and Mbarara, Uganda.

Cultivar	Mean root necrosis (percentage) along roots at intervals of 20 cm starting from the proximal end of the root (attached to the corm)[y]										Correlation coefficients of necrosis and distance from corm[z]
	20	40	60	80	100	120	140	160	180	200	
Suckers detached from established mats											
Namulonge											
Nabusa	20 a	13.7 a	13.0 ab	11.2	4.0	5.1	0.0				-0.56**
Pisang Awak	42 b	25.8 b	17.2 b	11.0	9.2	8.0	5.8	0.0	0.0	0.0	-0.62**
Sukali Ndizi	16 a	11.3 a	8.8 b	4.9	2.8	4.0	7.2	0.0	0.0		-0.48**
Ntungamo											
Nabusa	3.4 a	0.8 a									-0.68
Pisang Awak	60.0 b	35.0 b	22.3 a	14.8 a	3.8 a						-0.64**
Sukali Ndizi	78.0 b	63.0 b	42.3 b	27.5 b	19.5 b	12.1					-0.73
Three-month-old sucker derived plants											
Namulonge											
Nabusa	11.1 b	2.5	0.4	0.2	0.8	0.0					-0.59**
Pisang Awak	7.7 a	2.0	0.5	1.3	0.0	0.0					-0.49**
Sukali Ndizi	8.2 a	0.2	0.0	0.1	1.7	0.0					-0.52**
		ns	ns	ns	ns						
Ntungamo											
Nabusa	6.9	8.6	6.1	5.8	0.0						0.08
Pisang Awak	8.3	5.5	4.5	6.4	0.0						-0.25*
Sukali Ndizi	3.9	5.2	8.8	0.5	0.0						0.26
	ns	ns	ns	ns							
Mbarara											
Nabusa	0.2 a	1.0 b	0.2 a	0.0	0.0	0.0	0	0	0	0	-0.52**
Pisang Awak	5.1 b	0.7 a	1.5 b	3.4	1.5	0.0	0	0			-0.29*
Sukali Ndizi	3.9 b	2.9 b	2.1 b	0.0	0.0	0.0					-0.30*

[y]Means followed by same letter are not significantly different at P < 0.05 according to least square difference of the mean method.

[z]*, **, = Correlation coefficients significant at $P < 0.05$ or $P < 0.01$, respectively.

plants of Pisang Awak at Ntungamo where higher *Meloidogyne* densities were observed in the root tips. The results of this study also support earlier observations that these particular nematode species do not prefer a particular type of root tissue (Sarah, 1986) and have implications for assessing genotypes for nematode resistance, because they suggest that any section of a primary root can be assessed for nematode reproduction while damage varies with distance from the corm.

The nematode population composition in sword suckers detached from established mats was different from that observed in three-month-old sucker derived plants. It is probable that *R. similis* establishes itself faster and earlier than the other nematode species, as indicated by relatively higher *R. similis* population densities in the young sucker derived plants compared to suckers detached from established mats. Similarly, it is possible that *P. goodeyi* establishes itself slowly but has a high reproduction potential with time as observed in sword suckers detached from established mats at Ntungamo.

Pinochet (1977) and Hugon and Picard (1988) reported higher root necrosis near the corm. Our data confirm these observations. Highly negative correlation coefficients between root necrosis and distance from the corm were observed at Mbarara and Namulonge, while low correlation coefficients were observed at Ntungamo. This could be because of the presence of *R. similis* at Mbarara. However, root necrosis and nematode population densities were not correlated, which is in contrast to previous observations (Speijer *et al.*, 1998a; 1998b; 1999). A possible explanation might be that emerging roots become infected as they grow out of the corm into the rhizosphere in the proximity of previously infected older roots (Speijer *et al.*, 1997; Speijer *et al.*, 1998a). Consequently, increased damage occurs near the corm because of multiple nematode generations feeding in the same location. Another explanation for this discrepancy is that in previous studies (Speijer *et al.*, 1998a; 1998b; 1999a), only root segments collected relatively close to the corm were compared, whereas in our study root segments along the entire root length were compared.

These data suggest that differences in root development observed among *Musa* genotypes (Swennen *et al.*, 1986) are not likely to affect the locations for nematode reproduction and damage, but may influence the relative nematode densities among cultivars (Speijer *et al.*, 1999b).

ACKNOWLEDGEMENT

The Rockefeller Foundation, Nairobi Office, financed this study as part of Ph.D. research by the first author. The IITA Publications Review committee approved this Manuscript for publication as No. 99/006/JA.

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Received: *2.IX.1999*

Recibido:

Accepted for publication: *9.XII.1999*

Aceptado para publicación:

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