CORRELATIONS BETWEEN NEMATODE NUMBERS AND DAMAGE TO BANANA (*MUSA* AAA) ROOTS UNDER COMMERCIAL CONDITIONS

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ABSTRACT

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Relationships between numbers of *Radopholus similis* and total nematode numbers, and grades of root necrosis and root damage in commercial plantations with mixed *Musa* AAA cvs Grand Naine and Valery were investigated in a series of four experiments. Three different root damage indices, the Australian index, the Bridge and Gowen index and a Local index, were compared by assessing 100 randomly selected root samples. Correlation coefficients for the three indices were highly significant and varied between 0.38 and 0.40. In a subsequent experiment, working with the Local index, the correlation between *R. similis* and total nematodes, and root necrosis and damage was not improved when measuring one or both root halves. Using the Local Index, the above mentioned correlation was evaluated in randomly selected root samples from mother plants and their respective follower suckers in a third experiment. Mean root necrosis and damage grade in mother roots were double those of follower sucker roots. Correlation coefficients between *R. similis* and total nematodes, and root necrosis and damage in follower suckers ranged between 0.41 and 0.48, and were always significant. In contrast, these correlations using mother roots were never significant. In the final experiment, roots from mother plants and their respective follower suckers were arranged in 10 different damage classes. *R. similis* and total nematode numbers was correlated with root necrosis and damage for 0-5, 6-10 and 0-10 damage groups. Correlations were highest for root necrosis and *R. similis* in 0-5 interval, ranging between 0.62 ($P = 0.0002$) for mother roots and 0.75 ($P = 0.0001$) for sucker roots.

Key words: correlation coefficients, damage indices, *Musa* AAA, *Radopholus similis*, root damage, root necrosis.

RESUMEN

Moens, T., M. Araya, and D. De Waele. 2001. Correlaciones entre el número de nematodos y el daño de las raíces en banano (*Musa* AAA) bajo condiciones comerciales. Nematrópica 31:55-65.

La correlación entre el número total de nematodos de *Radopholus similis* y el grado de necrosis y daño de raíces se investigó en cuatro experimentos en plantaciones comerciales de banano (*Musa* AAA mezcla de los cvs Grand Naine y Valery). En el primer experimento, tres índices de medición del daño: el índice Australiano, el índice de Bridge y Gowen y un Índice Local se compararon después de analizar 100 muestras de raíces tomadas al azar. Las correlaciones obtenidas en los tres índices fueron altamente significativas y variaron de 0,38 a 0,40. En el siguiente experimento, usando el Índice Local, la correlación entre *R. similis* y nematodos totales con necrosis y daño en las raíces, no aumentó cuando la necrosis y el daño fue medido en una o las dos mitades. Continuando con el uso del Índice Local, dicha correlación se comparó usando muestras de raíces al azar de plantas madres y sus respectivos hijos de sucesión en el tercer experimento. El promedio del grado de necrosis y daño en las raíces de las madres fue el doble de los hijos de sucesión. La correlación en los hijos de sucesión varió entre 0,41 y 0,48 siendo siempre estadísticamente significativa. Por el contrario, en las madres las correlaciones nunca fueron significativas. En el último experimento, las raíces de las plantas madre y sus respectivos hijos de sucesión fueron clasificadas en 10 categorías de daño. *Radopholus similis* y nematodos totales fueron correlacionados con el grado de necrosis y daño en las categorías de daño de 0-5, 6-10 y 0-10. Las correlaciones fueron mayores entre necrosis y *R. similis* en el intervalo de 0-5, variando de 0,62 (P = 0,0002) en madres y 0,75 (P = 0,0001) en las raíces de los hijos de sucesión.

Palabras claves: coeficiente de correlación, daño de raíz, *Musa* AAA, necrosis de raíz, nematodos totales, *Radopholus similis.*

INTRODUCTION

Nematodes are an important cause of damage on banana (Davide and Marasigan, 1985; Fogain and Gowen, 1997; Speijer and Ssango, 1999). In Costa Rica, *Radopholus similis* is found most frequently and at highest density in banana roots, followed by *Helicotylenchus* spp., *Meloidogyne* spp. and *Pratylenchus* spp. (Araya *et al.*, 1995). With nematicide application, mean bunch weight increased between 20 to 40% (Araya and Cheves, 1997; Behm and Cordero, 1988). The mean cost of using nematicides can vary between US$300 and $450/hectare/year, depending on the product and the number of applications. In a commercial banana plantation, nematicides represent the second most important cost for pest control after control of the leaf disease Black Sigatoka caused by the fungus *Mycosphaerella fijiensis* (US$800-1400/hectare/year), accounting for between 5-9% of the variable costs.

In most commercial banana plantations, the development of nematode populations is monitored monthly. Parameters like total and functional root weight, and nematode numbers are estimated. Recommendations for use of nematicide are based on forecasted precipitation, changes in root weight and nematode numbers, anticipated nematicide biodegradation and product rotation history. In this decision process, nematode numbers play an important role, and 10 000 *R. similis*/100 g of functional roots is used as an economic threshold for nematicide application (Tarté and Pinochet, 1981; Gómez, 1980). However, in other producer countries more attention is given to root damage or root necrosis (Bridge and Gowen, 1993; Broadley, 1979; Gold *et al.*, 1994; Pattison *et al.*, 1997; Speijer and Gold, 1996). Probably the reason for this is that the root damage is the result of a complex of interacting biotic and abiotic factors including not only nematodes but also bacteria and fungi, soil type and drainage which influence the state of health of the banana roots. In Australia, root disease index is used as a parameter to decide nematicide application (Pattison *et al.*, 1997) and in Uganda root necrosis index is used to evaluate *Musa* germplasm for nematode sensitivity (Speijer and Gold, 1996).

The CORBANA nematode recovery procedure does not measure root damage directly, but it is taken into account through functional root weight. However, selection of functional roots is rather subjective. Therefore, it is necessary to confirm in commercial plantations in Costa Rica the existence of a significant correlation between nematode numbers and root necrosis and damage as found in other latitudes (Elsen *et al.*, 1998; Speijer and Gold, 1996; Speijer and Ssango, 1999). This knowledge, based on field sampling, is necessary to decide the need to implement chemical control measures. For the purpose of this research, root necrosis was defined as the proportion of blackened, necrotic root cortical tissue that reached the central root axis, while root damage was considered as root necrosis plus more superficial punctured or damaged root epidermis and or cortex.

The objectives of the present work were to determine 1) the index resulting in the highest correlations between nematode numbers and root necrosis and/or damage, and 2) the physiological plant stage at which correlations for these variables is highest.

MATERIALS AND METHODS

General procedure: Four experiments were conducted to determine the correlation coefficients between nematode numbers in primary roots and root necrosis and damage. In the first experiment, correlations between nematode population densities and published indices to measure root necrosis and damage in the field and a locally derived index were compared. Differences in correlations using one or both root halves were evaluated in the second experiment. The third experiment determined correlations between indices and nematode numbers in roots from either mother plants or suckers. Finally, in the fourth experiment, correlations were determined between nematode numbers and several discrete ranges of damage classes for primary roots.

All experiments were conducted in long-term ratoon commercial banana (*Musa* AAA, subgroup Cavendish) plantations cultivated with a mix of 'Valery' and 'Grand Nain' clones. The plant density varied between 1 700 and 1 800 plants/ha and the plantation age ranged from 7 to 9 years. Bunching plants were supported by aerial guying or by tying them to adjacent plants with double polypropylene twine. Normal cultural practices for Black Sigatoka, nematode and weed control and fertilization were used. Each production unit consisted of a bunch-bearing mother plant, a large follower sucker and a small granddaughter or peeper and was desuckered every 6 to 8 weeks. The plantations were not irrigated but average rainfall in 1999 varied from 3 652 to 4 554 mm distributed evenly throughout the year. A system of channels was present in each field to evacuate excess rainwater and prevent waterlogging. Mean daily maximum and minimum temperatures were 31 and 22.6°C respectively.

Plants were selected randomly for root sampling in areas without nematicide application at least during the last four months. Each sample consisted of the roots of 5 plants in the first three experiments and of 15 plants in the last experiment. The sampling sites were at the base either of the mother plant, from 1 to 8 days after flowering, or of the follower sucker or in the interspace between both plants. A hole of approximately 13 cm width × 30 cm depth was made and primary or cord roots with 5 to 10 mm diameter were selected.

After washing, roots were cut at 10-cm lengths and variable numbers of pieces, depending on the experiment, were taken at random from each sample. These root pieces were split longitudinally and measurements were made of necrosis/damage. Root necrosis was defined as the proportion of blackened, necrotic root cortical tissue that reached the central root axis. Root damage was considered as root necrosis plus more superficial punctured or damaged root epidermis and or cortex.

Nematodes were extracted by the Taylor and Loegering (1953) method. Both halves of longitudinally split roots, from which necrosis and damage were measured, were chopped into 2-3 cm length pieces and macerated in a kitchen blender for 10 sec at low and 10 sec at high-speed. The suspension was sieved through 500 µm, 150 µm and 20 µm nested sieves, and the nematodes recovered from the last sieve were counted under a stereoscopic microscope. Nematode numbers were expressed as individuals/100 g of fresh roots.

In all experiments, the correlations were determined between $\log_{10}$ of *R. similis* and $\log_{10}$ of total nematode number, and root necrosis and damage. Additionally, in the first experiment a frequency distribution was made.

Comparison of three different indices of root necrosis: One hundred samples from the monthly nematode monitoring program of CORBANA were used in this experiment. Root samples were from the interspace between the mother plant and the follower sucker. From each sample, 10 primary roots were chosen at random. Root necrosis in the same set of root parts was measured in three different ways: 1) according to the Australian index (Broadley, 1979, Pattison *et al.*, 1997), where root necrosis class was visually estimated, using one root half (0% damage = class 0, 0 < 25% = class 1, between 25 and 50% = class 3, between 50 and 75% = class 5 and >75% = class 7) and the index was calculated as [sum of all root necrosis class ratings/(total roots × 7)] × 10 instead of 100 to facilitate the presentation of the results; 2) according to a modified Bridge and Gowen index (Bridge and Gowen, 1993; Speijer and Gold, 1997), where root necrosis ratings were assigned to each half root piece (0 = 0% necrosis; 1 = 1-25% necrosis; 2 = 26-50% necrosis; 3 = 51-75% necrosis and 4 = 76-100% necrosis) and the index was calculated as the average of the products of each necrosis rating × the number of roots with that rating; 3) the Local index was calculated by first dividing the cumulative lengths of necrotic lesions (cm) on both halves of a root segment by 2× the root segment length, and then determining the average of these values for all roots in the sample.

Comparison of root necrosis and root damage using one or both root halves: Thirty root samples originating from CORBANA's monthly nematode monitoring program were used. Root necrosis and root damage were calculated separately on the same set of roots in two different ways. Root necrosis of the two edges of one root half was measured and divided by 2 or in the four edges of both root halves and divided by 4. The same procedure was repeated for root damage.

Correlation between nematode numbers and root necrosis and root damage: Thirty root samples from the mother plant and from its respective follower sucker, with a height between 1 and 1.50 m, were taken in an area of 4.6 hectares. Soil was classified as Fluvaquentic Eutropept, with a clay loam texture. Five samples were taken from recently flowered mother plants and their respective follower suckers every 6 days. Root necrosis and root damage was measured in mother and sucker roots using the Local index, as described in experiment 1.

Correlation between nematode numbers and classes of root necrosis and root damage: Root samples were collected weekly during 3 months in a 3-5 hectare area. The experiment was repeated in three different plantations with soils classified as Typic Hapludant, Aquic Distrudept and Fluvaquentic Eutropept, with a sandy loam, sandy clay loam or clay loam texture, respectively. After selecting the primary roots and measuring root damage and root necrosis, roots were placed in a specific damage class, ranging from 0 to 10. Each class contained between 7 and 11 replications, and for each replication from 4 to 10 root pieces were measured. Thus, ca. 70-90 root pieces in each class were evaluated which represents

70 to 90 m of primary roots originating from mother or follower suckers for combined 10 classes from each of the three farms. For the statistical analysis, these 10 classes were correlated individually with the corresponding nematode numbers. Separate correlation analyses were performed for the 0-5, 6-10 and 0-10 necrosis and damage classes, for mother and sucker roots respectively. A regression analysis was done of $\log_{10}$ of *R. similis* on damage class for mother and follower suckers, using data combined from the three trials. Differences in final nematode numbers, *R. similis* numbers, and necrosis and damage grade between roots from mother or follower plants were analyzed by a t-test. Mean nematode and *R. similis* numbers were transformed ($\log_{10}[x + 1]$) for analysis.

RESULTS

Of the nematodes extracted from roots, numbers of *Radopholus similis*, *Helicotylenchus* spp., *Meloidogyne* spp. and *Pratylenchus* spp. were counted and used to estimate total nematodes. There were no significant correlations between root necrosis or root damage, and numbers of either *Helicotylenchus* spp., *Meloidogyne* spp. or *Pratylenchus* spp. in any experiment (data not shown).

Comparison of three different indices of root necrosis: Of the total nematodes recovered from roots, *R. similis*, *Helicotylenchus* spp., *Meloidogyne* spp. and *Pratylenchus* spp. represented 89.8, 3.7, 6.0 and 0.5% respectively. The frequency distribution of the Australian (AI) and Local Index (LI) were similar, with 62 and 67% respectively of the samples belonging to classes 4 and 5 with 4-50% necrosis (Fig. 1). In the modified Bridge and Gowen Index (MBGI), 73% of the root samples were classified as grade 2, which corresponds to 26-50% necrosis. Highly significant correlation coefficients

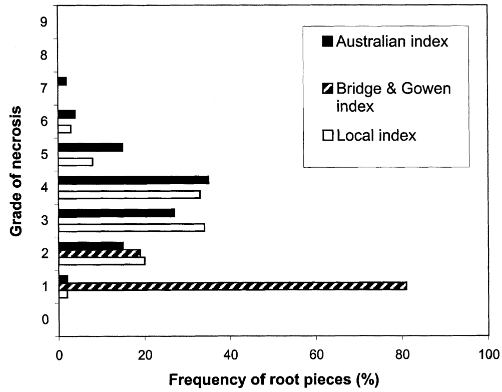

Fig. 1. Frequency distribution of banana (*Musa* AAA) root samples for the three root damage indices.

between *R. similis* or total nematode numbers, and root necrosis, ranging between 0.37 and 0.40, was found for the three indices used (Table 1).

Comparison of root necrosis and root damage using one or both root halves: From the total nematodes recovered, *R. similis*, *Helicotylenchus* spp., *Meloidogyne* spp. and *Pratylenchus* spp. represented 87.52, 10.73, 1.75 and 0% respectively. No difference was found in the correlation between *R. similis* or total nematodes, and root necrosis and root damage, using one or both root halves (Table 2).

Correlations between nematode numbers and root necrosis and root damage: R. similis, *Helicotylenchus* spp., *Meloidogyne* spp. and *Pratylenchus* spp. represented 93.25, 4.18, 1.40 and 1.16% of the total nematodes recovered, respectively. Significant correlation coefficients between *R. similis* or total nematodes, and root necrosis and root damage were found in suckers (Table 3). Correlations among these variable in mother plants were not significant. The average necrosis and damage grades were more than double in mother roots compared with sucker roots: 29.7 vs. 13.2% for root necrosis and 40.8 vs. 19.5% for root damage, respectively.

Table 1. Correlation coefficients[y] and associated probabilities between $\log_{10}$ of *Radopholus similis* and $\log_{10}$ of total nematode numbers per 100 g roots, and the necrosis and damage grade for each of the three indices in banana (*Musa* AAA).

Nematodes	Australian index	Modified Bridge & Gowen index	Local index
Radopholus similis	0.39 (P = 0.0001)	0.39 (P = 0.0001)	0.40 (P = 0.0001)
Total nematodes[z]	0.38 (P = 0.0001)	0.37 (P = 0.0002)	0.38 (P = 0.0001)

[y]N = 100 repelications.
[z]Total nematodes = *R. similis* + *Helicotylenchus* spp. + *Meloidogyne* spp. + *Pratylenchus* spp.

Correlation between nematode numbers and classes of root necrosis and root damage: R. similis, *Helicotylenchus* spp., *Meloidogyne* spp. and *Pratylenchus* spp. represented 96.45, 2.42, 0.64 and 0.48% of the total nematodes recovered, respectively. No interaction among farms was found for *R. similis* (P = 0.084) and total nematodes (P = 0.1337) and the data were pooled. The damage grade was directly related to numbers of *R. similis* numbers in roots (Fig. 2). All correlation coefficients between *R. similis* or total nematode numbers and root necrosis or root damage between 0-5 and 0-10 grade intervals were highly significant in mother and follower sucker roots (Table 4). However, a general plateau in the relationships at the 6-10 grade interval was reflected by lower correlation coefficients that were non-significant in half the cases. The correlation coefficient between *R. similis,* and root necrosis and root damage, especially in the 0-5 grade interval, was always higher in suckers than in mother roots. Despite wide dispersion of the data, quadratic models explained 43% and 49% of the variation in *R. similis* population density based on the damage grade in mother and follower sucker roots, respectively (Fig. 3). Total nematodes and *R. similis* numbers were significantly higher ($P \leq 0.0005$) in sucker than in mother roots (Table 5).

DISCUSSION

Correlation coefficients between *R. similis* or total nematode numbers and the three indices evaluated were very similar. These results are reasonable since the length of necrotic root cortical tissue always defined the grade of root necrosis in each of the three indices. The Local Index

Table 2. Correlation coefficients[y] and associated probabilities between $\log_{10}$ of *Radopholus similis* and $\log_{10}$ of total nematode numbers per 100 g roots, and the damage grade for each of four variables in banana (*Musa* AAA).

Nematodes	Necrosis of one half	Damage of one half	Necrosis of both halves	Damage of both halves
Radopholus similis	0.49 (P = 0.006)	0.48 (P = 0.007)	0.43 (P = 0.02)	0.39 (P = 0.04)
Total nematodes[z]	0.52 (P = 0.003)	0.54 (P = 0.002)	0.46 (P = 0.01)	0.43 (P = 0.02)

[y]N = 30 replications.
[z]Total nematodes = *R. similis* + *Helicotylenchus* spp. + *Meloidogyne* spp. + *Pratylenchus* spp.

Table 3. Correlation coefficients[y] and associated probabilities between $\log_{10}$ of *Radopholus similis* and of total nematode numbers per 100 g roots, and the grade of necrosis and damage, and the mean grade found in banana (*Musa* AAA).

Nematodes	Sampling place	Root necrosis	Root damage
Radopholus similis	Mother plant	0.28 (P = 0.13)	0.20 (P = 0.29)
	Follower sucker	0.42 (P = 0.02)	0.48 (P = 0.01)
Total nematodes[z]	Mother plant	0.20 (P = 0.29)	0.09 (P = 0.65)
	Follower sucker	0.41 (P = 0.02)	0.48 (P = 0.01)

[y]N = 30 repetitions.
[z]Total nematodes = *R. similis* + *Helicotylenchus* spp. + *Meloidogyne* spp. + *Pratylenchus* spp.

is the only one of the three indices that measures rather than estimates root necrosis. This may be an advantage in research; however, the measurements are time-consuming and under field conditions the use of one of the other two indices could be preferable. Similar correlations between nematode density and root necrosis or damage in either one or both root halves supports the standard practice of evaluating only one half of the split root segment to estimate root necrosis and damage (Bridge and Gowen, 1993; Broadley, 1979).

Although a highly significant correlation between nematode numbers and root

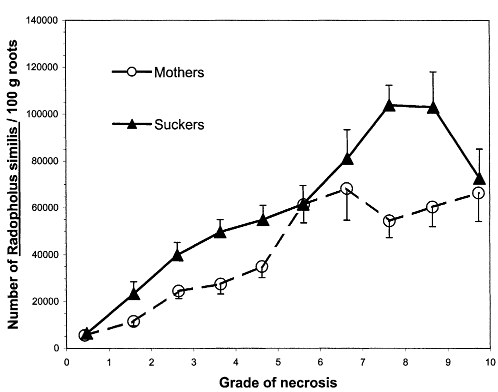

Fig. 2. Evolution of *Radopholus similis* numbers ± standard error in relation to banana (*Musa* AAA) root damage grade of mother plants and follower suckers.

necrosis and damage did exist, it is not advisable to depend solely on root condition to decide on implementation of nematode control practices; the irreversibility of root necrosis means it may not always reflect nematode activity. For smallholders with limited access to nematology facilities, these indices may be helpful to determine the state of banana root health. Nevertheless, the most efficient basis for nematode management decisions is continuous monitoring of nematode population density, because asymptomatic roots may support numerous nematodes.

Nematode population densities in follower sucker roots were always higher than in mother roots as reported by Araya and Cheves (1998). Correlations between nematode density and root damage were also higher in follower suckers than in mother plants, probably because the younger root tissue was more suitable for feeding nematodes. Because mother roots were exposed to other soil conditions (moisture, nematodes, fungi and bacteria) for a longer time than suckers, the relationship between nematodes and root damage was less evident. Speijer and Gold (1996) found a higher percentage of dead and rotted roots in older plants, which conforms with our observations and suggests that evaluating the role of nematodes in root necrosis

Table 4. Correlation coefficients[y] and associated probabilities between $\log_{10}$ of *Radopholus similis* and $\log_{10}$ of total nematode number per 100 g roots, and root necrosis and root damage, for mother and follower sucker roots respectively, in banana (*Musa* AAA).

Nematodes	Sampling place	Necrosis grade			Damage grade		
		0-5	6-10	0-10	0-5	6-10	0-10
Radopholus similis	Mother plant	0.64 (P = 0.0002)	0.126 (P = 0.70)	0.66 (P = 0.0001)	0.62 (P = 0.002)	0.063 (P = 0.57)	0.66 (P = 0.0001)
	Follower sucker	0.75 (P = 0.0001)	0.26 (P = 0.01)	0.70 (P = 0.0001)	0.74 (P = 0.0001)	0.30 (P = 0.0005)	0.71 (P = 0.0001)
Total nematodes[z]	Mother plant	0.66 (P = 0.0001)	0.124 (P = 0.32)	0.66 (P = 0.0001)	0.65 (P = 0.0001)	0.066 (P = 0.54)	0.65 (P = 0.0001)
	Follower sucker	0.63 (P = 0.0001)	0.27 (P = 0.007)	0.63 (P = 0.0001)	0.72 (P = 0.0001)	0.30 (P = 0.0006)	0.63 (P = 0.0001)

[y]N = 281 repetitions (3 farms × 10 classes × 7-11 repetitions).
[z]Total nematodes = *R. similis* + *Helicotylenchus* spp. + *Meloidogyne* spp. + *Pratylenchus* spp.

and root damage in the field can be better accomplished in follower sucker roots than in roots from mother plants.

Stronger correlations between nematode numbers with the damage grade interval of 0-5, compared to the interval 6-10 was more evident in follower suckers than in mother plants, and was likely due to the relatively smaller influences of nematode competition and of non-nematode factors. In roots with high necrosis and damage grades, increased variation in the nematode population dynamics probably resulted from changes in the availability of food resources. Hugon and Picard (1988) showed that nematodes moved out of necrotic banana root tissue and reinvaded healthy tissue.

Root damage attributable to nematodes in these experiments was likely due primarily to *R. similis,* which always comprised approximately 90% of the total nematode population. The correlation between *R. similis* numbers and root damage or necrosis was always highly significant, whereas no significant relationships were evident for *Meloidogyne* spp., *Helicotylenchus* spp. and *Pratylenchus* spp. The correlation coefficients reported here are within the range reported by other researchers (Elsen *et al.*, 1998; Speijer and Gold, 1996; Speijer and Ssango, 1999) and explained as much as 56% of the variation in root necrosis and damage. Correlations between nematode numbers (*R. similis* and total) and root necrosis and root damage were very similar; thus it is preferable to use necrosis as a root damage parameter, since it is easier to recognize. Moreover, superficial lesions are poor indicators of nematode damage because they are difficult to differentiate from other non-pathogen related discolorations.

Root necrosis is induced by either nematodes (Speijer and Ssango, 1999; Mateille, 1994; Boncato and Davide, 1992) or fungi (Castaing *et al.*, 1996; Loridat, 1989; Mateille and Folkertsma, 1991; Pinochet

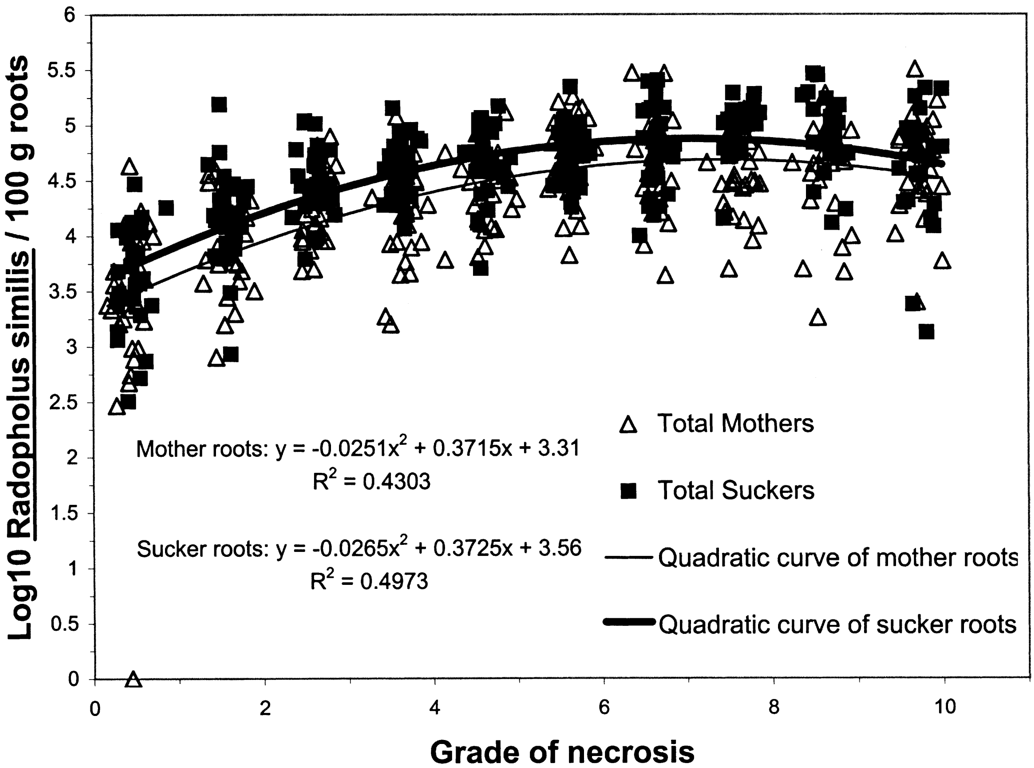

Fig. 3. Regression of $\log_{10}$ of *Radopholus similis* on banana (*Musa* AAA) root damage grade of mother plants and follower suckers. Each point is the average of 4 to 10 root pieces.

and Stover, 1980), and influenced by pH, plant cultivar, soil moisture and texture, and mechanical damage to the root system (Davide, 1980; Kobenan *et al.*, 1997). In the case of fungi, nematodes may induce a food base and increase their invasive potential (Blake, 1966). Non-obligate associations between nematodes and fungi exist in the field as demonstrated by Mateille and Folkertsma (1991). Fungi, mostly secondary colonizers of the wounds made by nematodes in the root tissue, affect the relationship between nematode numbers and percentage of root necrosis and damage. Despite this interaction, measurable relationships between root damage and nematode numbers is usually evident in the field (Sarah, 1991).

Additional factors might prove useful in future research on damage indices. Diameter of the primary root pieces evaluated for root necrosis and root damage ranged between 0.5 and 1 cm. This gave a high variation in root tissue volume, up to factor 4 if comparing the extremes The effect on correlations of controlling for root diameter should be evaluated. Only primary roots without secondary roots were used in these experiments. Relationships between nematode densities and damage to secondary and tertiary roots should be determined. Higher correlation coefficients obtained with sucker roots compared to mother roots reveals the importance of selecting the correct physiological stage of the plant. Perhaps control-

Table 5. Mean[x] nematode numbers/100 g of root ± standard error (SE) in mother and sucker roots in banana (*Musa* AAA).

Nematodes	Sampling place	Mean ± SE
Radopholus similis	Mothers	41 101 ± 2605 a[y]
	Suckers	57 792 ± 3175 b
Total Nematodes[z]	Mothers	42 859 ± 2617 a
	Suckers	58 972 ± 3203 b

[x]N = 281 repetitions (3 farms × 10 classes × 7-11 repetitions).

[y]Means followed by a different letter differed according to T-test.

[z]Total nematodes = *R. similis* + *Helicotylenchus* spp. + *Meloidogyne* spp. + *Pratylenchus* spp.

ling for sucker height (age) will further strengthen the correlations between damage and nematode numbers.

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