NEMATOLOGICAL REVIEWS—RESEÑAS NEMATOLOGICAS

HELICOTYLENCHUS MULTICINCTUS ON BANANAS: AN INTERNATIONAL PROBLEM[1]

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ABSTRACT

McSorley, R., and J. L. Parrado. 1986. *Helicotylenchus multicinctus* on bananas: an international problem. Nematropica 16:73-91.

The spiral nematode, *Helicotylenchus multicinctus* (Cobb) Golden, is widely distributed on bananas and plantains (*Musa* spp.) throughout the world. Although local damage is common throughout the tropics, losses and damage from this nematode are most serious in locations where *Radopholus similis* (Cobb) Thorne is absent, particularly in subtropical areas considered suboptimal for banana production. The nematode feeds within the outer layers of the root cortex, causing characteristic lesions, progressive root deterioration, toppling, and reduced yields, which ultimately bring about the rapid decline of plantations. The most common method of managing *H. multicinctus* on bananas and plantains has been through periodic application of nematicides, but performance and efficacy have varied, depending on a variety of factors. The nematode is readily spread to new locations on planting material, but spread can be retarded or prevented by paring, hot water, or chemical treatment of planting material.

Additional key words: geographical distribution, management, Musa acuminata, Musa balbisiana, plantain, review, spiral nematode.

RESUMEN

McSorley, R., y J. L. Parrado. 1986. *Helicotylenchus multicinctus* en el plátano: un problema internacional. Nematropica 16:73-91.

El nematodo espiral, *Helicotylenchus multicinctus* (Cobb) Golden, está ampliamente distribuido en los plátanos fruta y vianda (*Musa* spp.) a través del mundo. Aunque sus daños locales son comunes en los trópicos, las pérdidas y daños causados por éste nematodo son más serios en las localidades donde el *Radophlus similis* (Cobb) Thorne está ausente, particularmente en las areas subtropicales consideradas subóptimas para la producción del plátano. El nematodo se alimenta de las capas exteriones de la corteza de la raíz causando lesiones caracteristicas, un deterioro progresivo de la raiz, caida de las plantas y reducción de los rendimientos, lo cuál conlleva a la rápida declinación de las plantaciones. El método más común para manejar el *H. multicinctus* én los plátanos ha sido mediante aplicaciones periódicas de nematicidas, pero la actuación y eficiencia de estos tratamientos ha variado

dependiendo de diversos factores. El nematodo es facilmente deseminado a nuevas localidades por el material de plantación, pero dicha diseminación puede ser reducida o prevenida con la poda y limpieza y el tratamiento con agua caliente o productos químicos del material de plantación, lo cual retarda la declinación de las plantaciones.
Palabras claves adicionales: distribución geografica, manejo de plagas, Musa acuminata, Musa balbisiana, plantano vianda, revision, nematodo espiral.

INTRODUCTION

Bananas are one of the most important world food crops, with over 20 million tons produced per year, most for local consumption (60). Simmonds (60) states that most banana production is confined to tropical and subtropical regions having minimum winter temperatures of 15.6C (60F) and receiving at least 127 cm (50 inches) of rainfall per year (Fig. 1). Although starchy cooking bananas are usually referred to as plantains, distinction between bananas and plantains can be difficult, since most are triploid hybrids of two wild species, *Musa acuminata* and *M. balbisiana.*

The banana plant consists of a rhizome (often referred to as a "corm" or "mat") which produces a stalk or pseudostem formed from concentric layers of leaf sheaths. The true stem grows upwards from the rhizome through the center of the pseudostem, emerging from the top of the plant 10-15 months after planting, and producing a terminal inflorescence which later bears the fruit. Bananas are propagated vegetatively by removing pieces of the rhizome or preferably by detaching large suckers from the mat. The root system is extensive but relatively shallow, and as the fruit matures, the plant becomes top-heavy with increasing bunch weight, making it susceptible to toppling if strong winds or root damage should occur.

GEOGRAPHICAL DISTRIBUTION

Radopholus similis (Cobb) Thorne is the most serious nematode pest of bananas and plantains in most locations in which these crops are grown. The biology and management of *R. similis* on bananas and plantains has been reviewed by numerous authors (1,7,8,29,48,53,62,68), several of whom also discuss the many other species of plant-parasitic nematodes associated with *Musa* spp. (7,8,53,62,68).

After *R. similis, Helicotylenchus multicinctus* (Cobb) Golden is probably the most damaging nematode on bananas and plantains. This species was originally described in 1893 as *Tylenchus multicinctus* (12), and was transferred to *Helicotylenchus* in 1956 (24). More recent taxonomic descriptions are also available (57,58) to facilitate identification. Serious problems caused by this spiral nematode manifest themselves most readily in locations in which *R. similis* is rare or absent. The damage and decline caused by this nematode was first recognized in the late 1950's by Minz et al. (46) in Israel and soon afterward in Cuba by Venning (64). More recently, this nematode has been recognized as a major problem on bananas in several locations, including Cyprus (50) and Lebanon (59) in the Middle East, and in 1979 was associated with decline of the crop in diverse locations including the province of Salta in Argentina (15,16), southern Florida (41), and South Africa (33,34). In a recent survey conducted in West Bengal, India (47), *H. multicinctus* was widespread but *R. similis* was absent, while in Pakistan (54), spiral nematodes, including *H. multicinctus*, were found more frequently than *R. similis*.

In all probability, *H. multicinctus* may occur in most banana-producing regions of the world (53,68), having been reported associated with the crop on most continents and from numerous islands (Table 1). It has recently been reported from Italy, although not on bananas (67). In many of these locations, *R. similis* is also common on bananas and plantains, and receives more attention since it is the more damaging of the two species (29,65,66). High populations of *H. multicinctus* tend to build up when *R. similis* is locally absent (66), and so it is not unusual to find locally high populations of *H. multicinctus* even in regions where *R. similis* is often common, such as Nigeria (3,11), Trinidad (4), or the French West Indies (55). In Brazil, *H. multicinctus* is common and *R. similis* relatively infrequent on bananas in the state of Ceará (74), but both species are widespread in Rio de Janeiro (23) and Bahia (76), with *R. similis* considered the most damaging species on bananas throughout the country (75).

In general, *H. multicinctus* and *R. similis* often occur together on bananas and plantains in regions optimal for crop production, i.e., minimum temperature greater than 15.6C and at least 127 cm of rainfall. Regions where *R. similis* is consistently rare or relatively uncommon on bananas are located near the limits of temperature and rainfall requirements (Fig. 1), and may be considered suboptimal for banana production. It is in these locations where *H. multicinctus* is considered the principal nematode problem on the crop, although it often occurs together with *Meloidogyne javanica* (Treub) Chitwood or *M. incognita* (Kofoid & White) Chitwood. A notable exception is the Canary Islands (18), where *Pratylenchus* spp. appear to occupy the ecological niche of the absent *R. similis*, and are considered more damaging than *H. multicinctus*.

DAMAGE SYMPTOMS

The most frequently observed symptoms of *H. multicinctus* damage are the characteristic root lesions (Fig. 2), which have been illustrated

Table 1. Partial list of locations in which *Helicotylenchus multicinctus* has been reported on bananas and plantains.

Location (Reference)	Location (Reference)
Africa	South America
Angola (58)	Argentina (15*,16*)
Cameroun (38)	Brazil (23,58,71,74*,75,76)
Canary Is. (18)	Colombia (25,57,69)
Ethiopia (58)	Peru (35)
French Guinea (38)	Surinam (39,58)
Ivory Coast (38,57,58)	Venezuela (58)
Madagascar (37,66)	
Nigeria (2,3,11,57,58)	Central America
Reunion (66)	Belize (58)
Seychelles (58)	Costa Rica (57,69)
South Africa (33*,34,63)	El Salvador (57,68)
Tunisia (57)	Guatemala (57,69)
Uganda (58)	Honduras (51,57,69)
West Africa (38,66)	Mexico (68)
Zimbabwe-Zambia-Malawi (40,58)	Nicaragua (68)
	Panama (57,68)
Asia-Middle East	
Bangladesh (57)	West Indies
Brunei (58)	Cuba (17,19*,57,58,64*)
Cyprus (50*, 58)	Dominican Republic (57,58,68)
India (47*,57,58)	French West Indies, Martinique (55)
Israel (46*,57,61)	Jamaica (30,31,32,58)
Lebanon (59*)	St. Lucia (28)
Malaysia (57)	Trinidad (4)
Pakistan (54*)	Windward Islands (20,58)
Philippines (57)	
Australia-Pacific	North America
Fiji (12,58)	California (57)
Hawaii (56,57)	Florida (41*,42,44,57)
New South Wales (5)	
Queensland (9,13,57)	
Samoa (58)	

*Reports in which *H. multicinctus* is considered the principal nematode problem on bananas and plantains.

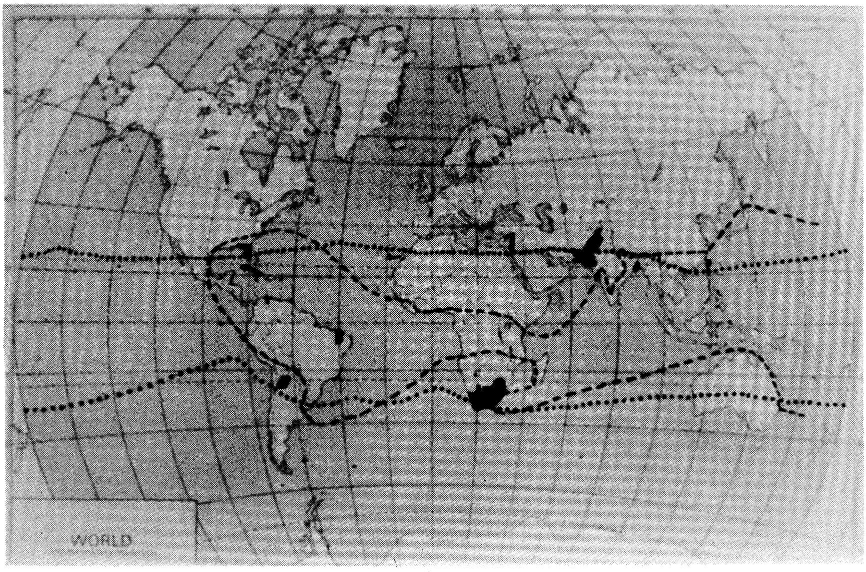
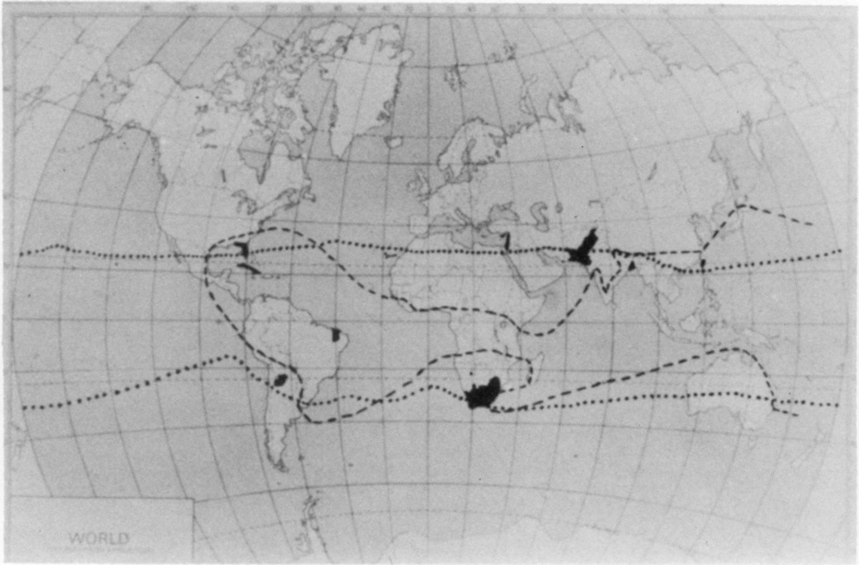


Fig. 1. Geographic limits to banana production. Most areas enclosed by dotted (.....) lines have minimum winter temperatures greater than 15.6C (60F); most areas enclosed by dashed (-----) lines receive at least 127 cm (50 inches) of rainfall per year. Shading indicates areas in which *Radopholus similis* is not reported to be the major nematode problem on bananas.

by many sources (7,8,18,46,62,68). Lesions are shallow and superficial, reddish-brown to black in color, and relatively discrete and unlikely to coalesce except in very heavy or advanced infestations. They are confined to the root cortex, and a longitudinal section cut from a banana root will reveal necrosis only near the outer surface, with deep internal lesions (typical of *R. similis*) absent (18,68). Very small feeder roots show progressive stages of decay (46), and heavily infested roots can be visually distinguished from those harboring low populations (59). Lesions may be colonized by *Fusarium, Rhizoctonia,* or *Cylindrocarpon* (8,59). Extensive root necrosis results in debility and dieback (8,16), and toppling will occur in some instances (16,19,41). The productive life of the plantation is greatly reduced, with drastic drops in production 2-3 years after planting (46).

Blake (6) has examined the invasion of roots by *H. multicinctus* in detail. The epidermis of banana roots grown under asceptic conditions was penetrated by *H. multicinctus* adults 36 hr after inoculation. After 4



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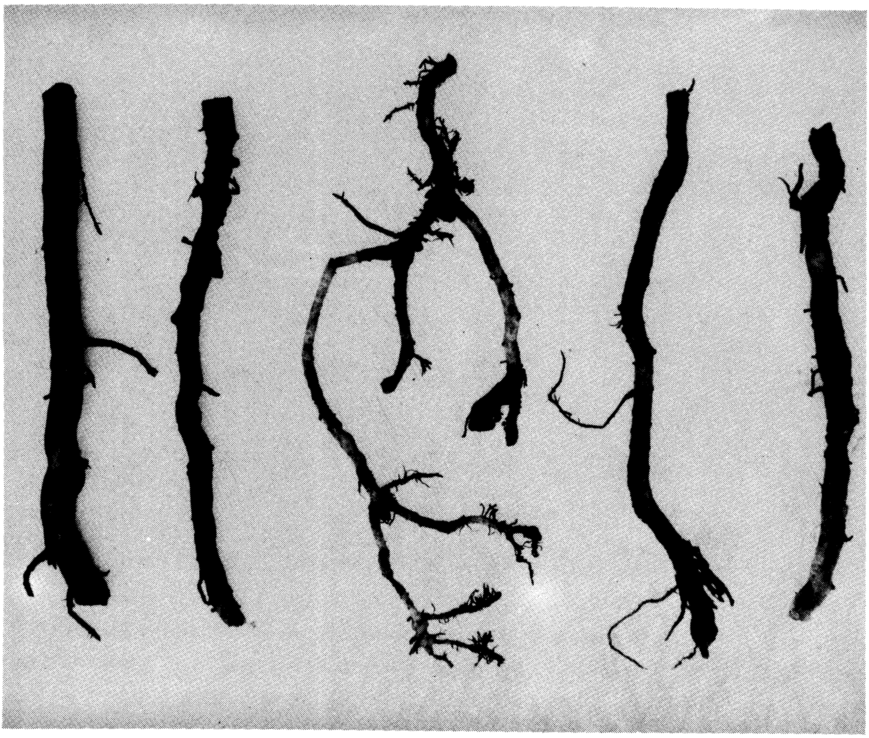

Fig. 2. Banana roots damaged by *H. multicinctus*.

days, some nematodes had completely entered the root cortex to a depth of 4-6 cells. The endoparasitic nematodes fed directly on the parenchyma cells of the root cortex causing various types of cellular damage including contraction of cytoplasm, distortion or rupture of cell walls, or increase in the size of the nucleus. Damaged cells became discolored and some became necrotic. All histological changes were confined to the sub-epidermal parenchymal tissue in the cortex, with little evidence of any migration through the cortex.

Nematodes of both sexes and all life stages, including clusters of eggs, have been found within the outer root cortex (79), and so it is likely that the nematode can complete its life cycle there. Because substantial numbers of *H. multicinctus* occur within roots, population estimation may require both soil and root samples to be collected. Modifications of Coolen and d'Herde's blender maceration-centrifugation method (14) generally yield the greatest recovery of *H. multicinctus* from banana roots (45). If extraction methods involving incubation are used, then the storage temperature of the samples becomes an important con-

Fig. 2. Banana roots damaged by *H. multicinctus*.

sideration. Obviously, it is best to process samples immediately after collection (29), but if storage is necessary, much greater recovery of *H. multicinctus* from soil and roots was obtained from samples stored at 27-30C than from those stored at 5-8C.

Population assessment can be difficult because of great variation in *H. multicinctus* densities within a plantation (R. McSorley, J. L. Parrado, and V. H. Quimi, unpublished), and is further complicated by seasonal fluctuations in nematode density. Attempts have been made to correlate densities with rainfall, but with variable results. In Nigeria, Badra and Caveness (2) found strong negative correlations between *H. multicinctus* density and total monthly rainfall, average daily rainfall per month, or number of rain days per month, lending statistical support to their observation of maximum nematode populations during the dry season. In a second test (11), weaker, but still significant negative correlations were also apparent for *H. multicinctus*, while *M. javanica* showed positive correlations. In another instance (3), *H. multicinctus* exhibited no significant correlation with rainfall. Each of these Nigerian studies (2,3,11) utilized loamy sand or sandy loam soils. In Jamaica, Hutton (30) found a significant negative correlation between *H. multicinctus* density and rainfall at a clay loam site (Point Hill), but a significant positive correlation at another site, having heavy clay (Orange River), and attributed this discrepancy to an incident of very heavy rainfall at Point Hill which was followed by a population decrease. These observations are supported by data on Rockdale fine sandy loam from Florida (42), where a positive correlation between *H. multicinctus* and number of rainfall days was observed. Only a very weak relationship between density and total rainfall was found, since total rainfall was distorted by one day of extremely heavy rainfall. In southern Florida, maximum populations of *H. multicinctus* usually occur at the end of the rainy season, and exhibit declines during the drier months (42). Description of seasonal population fluctuations of *H. multicinctus* evidently requires further clarification, since cycles are strongly influenced by soil type and by quantity and quality of rainfall. Incidents of unusually heavy rainfall may distort the usual nematode density-rainfall relationships.

MANAGEMENT

Field application of nematicides. By far the most important means of managing *H. multicinctus* and other plant-parasitic nematodes on banana has been the application of nematicides to infested sites. Some recent examples are provided (Table 2) in which nematicides had been used to reduce populations of *H. multicinctus* or closely related species in infested plantings of bananas or plantains. Although many of the materials tested were effective, there is much variability in performance, un-

Table 2. Nematicide field trials in which *Helicotylenchus multicinctus* or *Helicotylenchus* spp. were present.

Location (Reference)	Nematicide	Rate(s)	Population reduction compared to control[y]	Yield increase compared to control	Remarks[z]
Jordan Valley, Israel (46)	DBCP	10-20 L/1000 m^2	Reduced, but no data	Significant in bunch weight and other categories	Application in irrigation water more effective than application to dry soil.
Homestead, Florida (42)	ethoprop	3.0-6.0 g ai/mat	No differences	No differences	Unusual rocky soil type; *M. incognita* also present.
Homestead, Florida (44)	Vapam	935 L/ha	Little overall effect	Not evaluated	Unusual soil type; *M. incognita* also present.
	oxamyl	0.5-1.0 g ai/plant	Little overall effect	Not evaluated	
Roseau, Lucia (28)	DBCP	3.0-15.0 ml/plant	Significant in 3 of 3 tests	Significant in 2 of 3 tests	*R. similis* also present, and counts of this species and *H. multicinctus* are combined.
	phenamiphos	3.0 g ai/plant	Significant in 2 of 3 tests	Significant in 3 of 3 tests	
	oxamyl	2.0-6.0 g ai/ plant	Significant in 1 of 2 tests	Significant in 2 of 2 tests	
	carbofuran	1.5-2.5 g ai/ plant	Significant in 2 of 3 tests	Significant in 2 of 3 tests	

	ethoprop	5.0 g ai/plant	Significant in 1 of 1 tests	Significant in 1 of 1 tests	
Rincón, Puerto Rico (52)	oxamyl	2.5-10.0 cm^3/ plant	Up to 74% reduction	Significant at all rates	*R. similis* present in high populations; counts are for *Helicotylenchus* spp.; "spot gun" application.
Santa Isabel, Puerto Rico (52)	oxamyl	2.5-10.0 cm^3/ plant	Up to 91% reduction	Not evaluated	
Guácimo, Costa Rica (22)	aldicarb	3.0-9.0 kg ai/ha	Significant at highest rate	Significant at highest rate	*R. similis* present; *Helicotylenchus* species not identified.
	aldoxycarb	6.75-13.5 kg ai/ha	Not significant	Not significant	
	DBCP	19.35 L/ha	Not significant	Not significant	
Guácimo, Costa Rica (21)	DBCP	12.9 cm^3/plant	Significant at all rates	Not significant	*R. similis* present in high populations; *Helicotylenchus* identified to genus.
	aldicarb	2.0-6.0 g ai/plant	Significant at all rates	Significant at some rates	
	aldoxycarb	4.5-9.0 g ai/plant	Significant at all rates	Significant only with plant diameter	
Bahia, Brazil (77)	aldicarb	4 g ai/plant x 2	Reduced from control	Increased yield, reduced toppling	*R. similis* present and common; two applications.
	carbofuran	4 g ai/plant x 2	Reduced from control	Increased yield, reduced toppling	
	DBCP	4 g ai/plant x 2	Reduced from control	Increased yield, reduced toppling	

Table 2. Nematicide field trials in which *Helicotylenchus multicinctus* or *Helicotylenchus* spp. were present (continued).

Location (Reference)	Nematicide	Rate(s)	Population reduction compared to control[y]	Yield increase compared to control	Remarks[z]
	fensulfothion	4 g ai/plant x 2	Reduced from control	Increased yield, reduced toppling	
	oxamyl	4 g ai/plant x 2	Reduced from control	Increased yield, reduced toppling	
Nigeria (2)	aldicarb	1.5 g ai/plant	Some decreases evident	Some growth increases	*M. javanica* also present; applications in combination with giberellic acid.
Nigeria (3)	aldicarb	7 g ai/plant	Some reductions	Significant increases in bunch weight	*M. javanica* also present; 3 applications—3-2-2 g ai/plant better than 2-3-2 for *H. multicinctus*.
	carbofuran	7 g ai/plant	Variable		
	oxamyl	7 g ai/plant	Variable		
	miral	7 g ai/plant	Some reductions	"	
Nigeria (11)	carbofuran	3.0 g + 1.2 g ai/plant	Reduced from control	Significant	*M. javanica* also present; soil or foliar application of oxamyl.
	oxamyl	3.0 g + 1.2 g ai/plant	Reduced by soil application more than foliar	Significant for soil and foliar applicacations	

South Africa (33)	aldicarb	1.5-3.0 g ai/mat	Significant for all rates and materials	Not evaluated	
	aldoxycarb	3.75-15.0 g ai/mat		Not evaluated	
	ethoprop	2.0 g ai/mat	"	Not evaluated	
	phenamiphos	1.2-4.0 g ai/mat	"	Not evaluated	
	oxamyl	2.0-4.0 g ai/mat	"	Not evaluated	
South Africa (34)	phenamiphos	1.2-2.4 g ai/mat x 5	Reduced by both rates; 2.4 g better	Not significant	*M. incognita* also present.
	aldicarb	2.5-5.0 g ai/mat x 4	Reduced at all rates	Significant for stem diameter	

[y]Population reductions refer only to *Helicotylenchus* spp., unless counted together with *R. similis*.
[z]Nematodes other than *H. multicinctus* which may have influenced yield results.

derscoring the need to consider a number of factors before deciding upon a specific nematicide treatment.

Aside from cost and availability, an increasing concern in the selection of a nematicide are restrictions and regulations imposed by governments. For example, of the numerous nematicides available for use on banana, only ethoprop is registered for use on the crop in Florida and other parts of the United States (44). A few materials, such as ethylene dibromide, are phytotoxic to bananas (44). Granular formulations are the most widely used (Table 2), since they are convenient to apply and compatible with plant health and vigor, two important qualities in a system in which periodic application is necessary. As an alternative to application of granular nematicides to soil, oxamyl can be applied to foliage, from which it can be translocated to roots and prevent invasion by *H. multicinctus* (27). A "spot-gun" is available for convenience of applying oxamyl to foliage, soil, or in leaf axils (52). Dosage and application rates are critical considerations which may vary with location. For example, phenamiphos at very low rates easily controlled *H. multicinctus* in West Africa (65), but higher rates gave better results in trials in South Africa (34). When applications are repeated at regular intervals, an initial high dose can be more effective in reducing *H. multicinctus* than other dosage sequences (3). Pattern of application is also an important consideration, since *H. multicinctus* can be present in roots at a relatively great distance from the pseudostem. With this in mind, Strich-Harari *et al.* (61) recommended injection of DBCP in two concentric circles around the pseudostem rather than at one fixed location. Local conditions can influence the efficacy of nematicides applied to soil, particularly granular nematicides. Frequency and amount of rainfall can alter recommendations on sequence and dosage of granular nematicides (3). Application of ethoprop or oxamyl to alkaline, rocky soils has been unsuccessful in most cases (42,44), but soil pH in itself may not be a factor in efficacy, since Robalino *et al.* (52) were successful with oxamyl application both on acidic and on alkaline soils. A final reason for inconsistency in assessing *H. multicinctus* control with nematicides is that other parameters influencing banana yield, such as *R. similis* or soil insects, are also influenced by most materials tested.

Treatment of planting material. Once established in a new location, *H. multicinctus* can be difficult to eradicate, due to its persistence on a wide range of hosts. In some locations, however, the nematode is not present in natural or even cultivated sites until it is introduced on infested planting material (39,44,46,61). Appropriately, there has been some emphasis on treatment of planting material to prevent colonization of banana plantations by *H. multicinctus*, thereby avoiding the nematicide applications discussed in the preceding section.

Nematicide treatment of planting material, as used against *R. similis* (10), would probably be useful in management of *H. multicinctus* as well. Tests with various materials for this purpose, such as carbofuran, miral, diazinon, aldicarb, aldoxycarb, or oxamyl, have given encouraging results (73). Paring of banana seed pieces, often used in combination with chemical treatment for management of *R. similis* (1,10), can be useful for management of *H. multicinctus* as well (44). Since *H. multicinctus* occurs in root stubble rather than the corm itself, less severe paring than that used for *R. similis* is satisfactory for removing *H. multicinctus* from planting material (44).

For control of *R. similis* on planting material, immersion in hot water at 55C for 20 min is recommended (7,10), but reduced plant growth and emergence is occasionally noted when such a severe temperature-time regime is used (73). Since *H. multicinctus* infestation of planting material is much more superficial than infestations with *R. similis*, less severe treatment regimes may be satisfactory when only *H. multicinctus* is present. In the laboratory, *H. multicinctus* was killed by immersion in hot water at 50C for 5 min or longer, whether the nematodes were exposed in glass vials or in roots (43,44). A hot water bath at about 52C for 7.5-10 min has been useful for field treatment of planting material containing *H. multicinctus* (44).

Resistant cultivars. Use of resistant or tolerant cultivars has not been an important means of managing *H. multicinctus* since the nematodes readily invade and reproduce on clones of differing ploidy (26). Oramas and Roman (49) claim that *H. multicinctus* is important on the *M. acuminata* (AAA) group, but is not found on plantains (*M. acuminata* x *M. balbisiana* [AAB] group) in Puerto Rico. However, survey data from Luc and Vilardebo (7,8,38) reveal *H. multicinctus* associated with numerous varieties in both the *M. acuminata* (AAA) and *M. acuminata* x *M. balbisiana* (AAB) groups. The nematode damages all three cultivars commonly grown in southern Florida (41): 'Burro' (ABB group), 'Manzano' (AAB group), and 'Macho' (AAB group), with 'Macho' the most severely affected (44). Zem and Rodrigues (76) found *H. multicinctus* in roots of a variety of different cultivars in Brazil; subsequent investigations have suggested some degree of tolerance in the cultivars 'Prata' and 'Mysore' (72,78).

Other management strategies. Little information is available on managing *H. multicinctus* by crop rotation or fallowing. However, these methods may not be particularly useful once *H. multicinctus* is established in a given site, because the nematode has a wide host range (58) and because little information exists on its survival in the absence of a host (7). Flooding of planting sites for 3 months has been used as a control measure in Surinam (39), and while flooding did greatly reduce populations compared to unflooded plots, nematode populations did eventually reestablish themselves in the flooded sites. Flooding is considered beneficial in rehabilitating older plantations, since older plantings usually have developed the highest nematode populations (39).

In summary, the most effective method of managing *H. multicinctus* on bananas and plantains is by preventing introduction on infested planting material. Once introduced into a plantation, management with nematicides is more difficult and likely to require periodic monitoring and subsequent applications.

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