

## THE ROOT-KNOT NEMATODES OF BANANA

*Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949

*Meloidogyne javanica* (Treub, 1885) Chitwood, 1949

Dirk De Waele and Romulo G. Davide (1998)

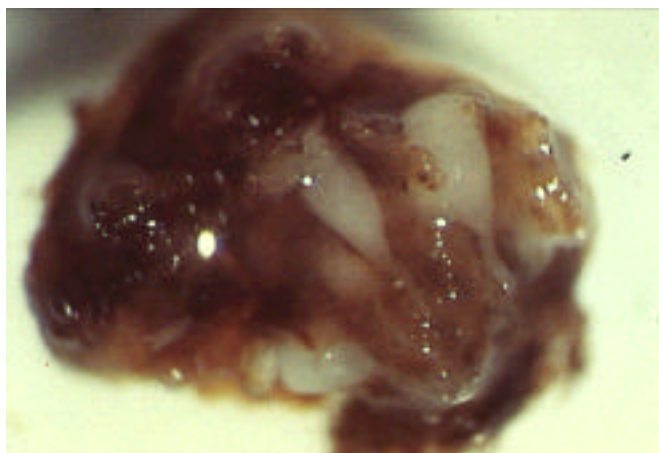
The root-knot nematodes *Meloidogyne incognita* and *Meloidogyne javanica* occur on banana and plantain roots wherever this crop is grown. *Meloidogyne arenaria* and occasionally some other *Meloidogyne* species may also be found associated with banana and plantain. In spite of their widespread occurrence and high abundance, root-knot nematodes are not considered important pathogens of banana and plantain. Root-knot nematodes often occur on banana roots together with the other pathogenic nematode species *Radopholus similis* and *Pratylenchus* spp. The damage caused by these other nematode species is more visible (root necrosis) and more destructive (toppling of plants) than the symptoms (galling) and other adverse effects caused by *Meloidogyne* spp. Moreover, *R. similis* and, to a lesser extent, *Pratylenchus* spp., tend to outnumber and eventually replace root-knot nematode populations. When they occur together, the root lesion inducing nematodes destroy the root tissues and thus provide feeding sites for *Meloidogyne* spp. There are indications however, that the importance of root-knot nematodes may have been overlooked, especially in areas where *R. similis* is not present.

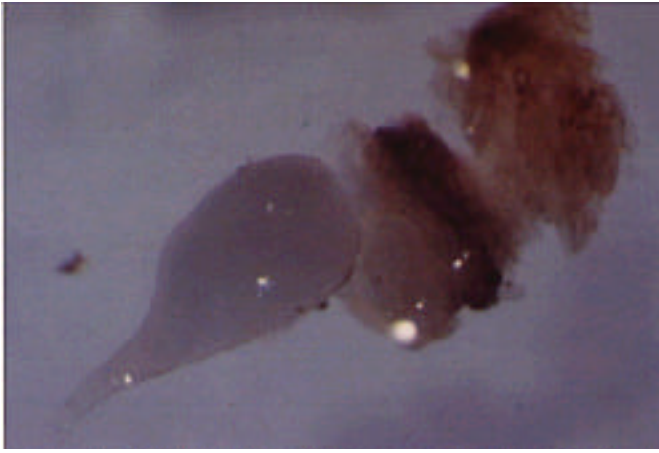
### Distribution

*Meloidogyne incognita* and *M. javanica* occur worldwide. On banana and plantain they can become abundant in areas where either the climate is too cold for *R. similis*, *R. similis* has not been introduced (as it commonly has been with dessert bananas of the Cavendish (AAA) subgroup) or *Pratylenchus goodeyi* is not present. Such areas can be found in the Mediterranean (e.g. Crete and Lebanon), in the subtropics (e.g. South Africa), in the tropics at higher altitude in South America (e.g. the Andes in Colombia) and in the lowlands in Africa (e.g. Ghana, Tanzania) where dessert bananas of the Cavendish subgroup were not introduced on a large scale and *R. similis* was therefore not spread with infected planting material. In the highlands of Africa, *M. incognita* and *M. javanica* are much less abundant because of the occurrence of *P. goodeyi*.

In contrast, in Asia, especially in Southeast Asia which is considered the centre of origin of *Musa*, *Meloidogyne* spp. are often the most common and abundant nematode species on the many native diploid and triploid varieties grown as cooking and dessert bananas. In Malaysia, popular local cultivars such as Pisang Mas (AA, syn. Sucrier), Pisang Berangan (AA, syn. Lakatan), Pisang Rastali (AAB, Silk subgroup), Pisang Nangka (AAB), Pisang Tanduk (AAB), and Pisang Embung (AAA, syn. Gros Michel) are all susceptible to *M. incognita*. Stunting, thin pseudostems and small fruit bunches are commonly observed on these cultivars. In Asia, *Meloidogyne* spp. may also occasionally be predominant on dessert bananas of the Cavendish subgroup. In the Philippines, *M. incognita* and *M. arenaria* are widely distributed and occur at a high level on dessert bananas of the Giant Cavendish type. For example, in Davao 82% of all root samples examined were infected with an average population density of 3,539 nematodes per 100 g fresh roots. In West Malaysia, *M. javanica* was omnipresent in a commercial plantation of dessert bananas: the average number of infective second-stage juveniles (J<sub>2</sub>) recovered from 200 ml of soil was 2,300 and the plants showed extensive galling.

*Cross section through a gall on a plantain root showing swollen female bodies with slender necks of root-knot nematodes (Meloidogyne spp.).*



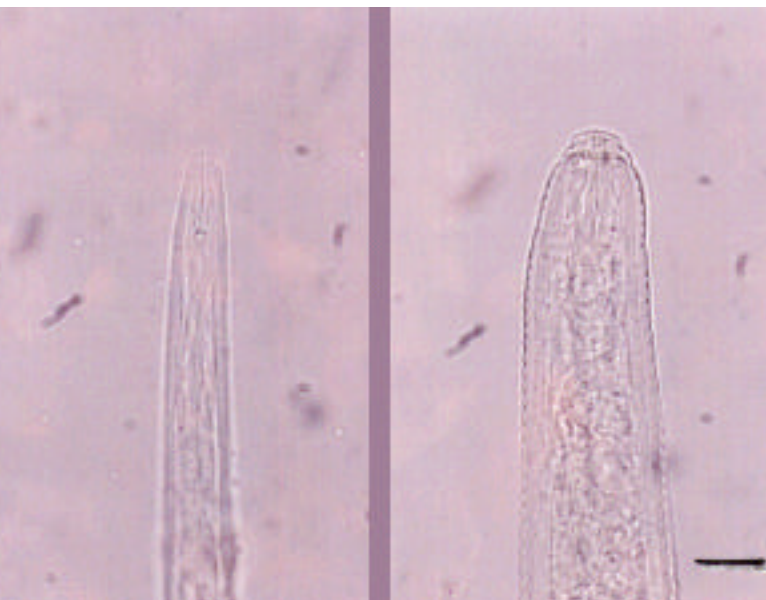


Dissected female and egg mass (*Meloidogyne* spp.).

## Life cycle, symptoms and damage

*Meloidogyne* spp. are sedentary endoparasites. Mobile second-stage juveniles ( $J_2$ ) emerge from the eggs, move towards the roots and penetrate the roots either at the root tip, or in regions of previous penetration or where minor wounds are present. In the root, the  $J_2$  invade the endodermis and, on entering the stele, induce multinucleate giant cells derived from vascular parenchyma or differentiating vascular cells in the central part of the stele. The formation of these giant cells disturbs or blocks the surrounding xylem vessels. Multiplication of cortical cells is also induced, resulting in the formation of the characteristic galls. The  $J_2$  feed on these giant cells and moult three times to form the adult females which enlarge rapidly. Dissection of galls reveals the typical swollen females in various stages of maturation. At maturity the females are saccate. Reproduction is parthenogenetic. A high percentage of males are

Head region of *Meloidogyne*:  
2nd-stage-juvenile (left) and male (right).  
Bar = 20 microns.



produced only in adverse conditions. The eggs are laid within a gelatinous matrix to form an external egg sac or egg mass. A single egg sac can contain several hundred eggs. In thick, fleshy primary roots the egg masses may not protrude outside the root surface. On banana and plantain, the complete life cycle takes between four and six weeks. Different *Meloidogyne* species can be observed in the same gall. Root-knot nematodes may also colonize the outer layers of the corm up to 7 cm deep

On banana and plantain, the most obvious symptoms of *Meloidogyne* spp. infection are swollen, galled primary and secondary roots. Sometimes the root tips are invaded and there is little or no gall formation, but root tip growth ceases and new roots proliferate just above the infected tissues. Infected plants may have a much lower number of secondary and tertiary roots. Above ground symptoms caused on banana by *M. javanica* in Pakistan included yellowing and narrowing of leaves, stunted plant growth and reduced



2nd-stage-juvenile  
tail region of  
*Meloidogyne*  
*incognita*.  
Bar = 20 microns.



Male tail region  
of *Meloidogyne*  
*incognita*.  
Bar = 20 microns.

fruit production. In the Philippines, a yield loss assessment experiment under field conditions with *M. incognita* on dessert bananas of the Giant Cavendish type showed that an inoculum level of 1,000 J<sub>2</sub> per plant resulted in 26.4% yield loss, 10,000 J<sub>2</sub> in 45.4 % yield loss and 20,000 J<sub>2</sub> in 57.1% yield loss compared with the uninoculated plants.

In banana and plantain roots, *Meloidogyne* spp. often occur together with soil-borne fungi but synergistic effects between these two groups of pathogens have not been documented, although there are indications that such effects may exist. In Yemen, higher levels of root rot were observed in banana plantations where *M. incognita* and soil-borne fungi (*Fusarium* and *Rhizoctonia* spp.) were present together.

### Cultural, chemical and biological control

*Meloidogyne* spp. may be spread with infected planting material. Infected corms can be disinfected of root-knot nematodes by peeling, followed by hot water treatment (at 53 to 55° C for 20 minutes) or treatment with a nematicide before planting.

Root-knot nematodes have a wide host range, especially dicotyledonous plants, which are often present in areas where banana and plantain are growing. Therefore special attention should be given to the maintenance of weed-free fallows and the selection of cover crops or associated crops in intercropping and rotation systems. Fallowing to eradicate root-knot nematodes may however be ineffective since it was reported in Cuba that *Meloidogyne* spp. persisted in the soil in the absence of bananas for up to 29 months. In India, intercropping with *Coriandrum sativum*, *Sesamum indicum*, *Crotalaria juncea*, *Tagetes erecta* and *Acorus calamus* significantly reduced the populations of *M. incognita* on bananas of the Robusta type (Cavendish subgroup) in field trials. The same effect on *Meloidogyne* spp. was obtained in crop rotation trials with Pangola grass, maize and sugarcane in Cuba and with *Tagetes patula* in South Africa. Because of the period of flooding, rotation with paddy rice may also drastically reduce root-knot nematode populations.

Most of the widely grown banana and plantain cultivars are susceptible to root-knot nematodes. However, large scale screening of banana and plantain genotypes has revealed the existence of sources of resistance to *Meloidogyne* spp. In the Philippines, out of 90 *Musa* genotypes examined for susceptibility (nematode reproduction rate) and sensitivity (damage caused by nematodes) to *M. incognita*, nine cultivars (Alaswe, Dakdakan, Inambak, Pastilan, Pugpogon, Maia Maole, PaaDalaga, Sinkler and Viente Cohol) showed resistance. These cultivars had a gall index of 1-2 indicating



Galling of banana roots caused by root-knot nematodes.

only slight root gall formation with generally few nematodes infecting the roots.

Numerous field experiments have shown the effectiveness of various nematicides against root-knot nematodes. Dipping the corms for 10 minutes in a nematicide solution as a pre-planting treatment may protect the plants for a few months against nematode infection. Nematicides found effective included dibromochloropropene (DBCP or Nemagon, today forbidden in numerous countries), the organophosphates: ethoprophos and fenamiphos, and the carbamates: aldicarb and carbofuran. Immersion of peeled corms in 1% sodium hypochlorite (NaOCl) for 5 or 10 minutes also controlled *Meloidogyne* spp. and is considered as an effective, low cost and non-toxic pre-planting treatment. Likewise, it was shown that pre-planting fumigation with ethylene dibromide (EDB, today forbidden in numerous countries), dichloropropane-dichloropropene (D-D) or methyl bromide and post-planting soil treatment with most organophosphates (ethoprophos, cadusaphos, fenamiphos, isazofos, terbufos) and carbamates (aldicarb, carbofuran, oxamyl) applied several times a year, may significantly control root-knot nematodes in estab-

lished banana plantations and improve plant growth and yield. By studying the seasonal fluctuation pattern of the nematodes, an effective nematicide control programme can be developed with nematicides being applied when the population approaches a critical level, usually at the onset of the rainy season. In Puerto Rico, oxamyl applied four times with 30-day intervals during the growing season to the leaf axils of Giant Cavendish bananas effectively controlled *M. incognita*.

In the Philippines, root extracts from African marigold (*Tagetes erecta*), ipil-ipil (*Leucaena leucocephala*), Bermuda grass (*Cynodon dactylon*) and makahiya (*Mimosa pudica*) were highly effective against *M. incognita* egg hatching and infestation. The performance of these root extracts was comparable to that of the chemically based nematicides. Also leaf extracts from Kaatoanbangkal (*Anthocephalus chinensis*) and water lily (*Eichornia crassipes*), and bulb extracts of garlic (*Allium sativa*) and onion (*Allium alia*) were effective against *M. incognita*. Characterization of the active nematicidal ingredient showed a phenolic aldehyde from *A. chinensis*, a carbolyxic acid from *E. crassipes* and a ketone in *A. cepa*.



Also in the Philippines, culture extracts of 17 species of microorganisms were evaluated under laboratory and greenhouse conditions for nematicidal activity against *M. incognita* based on mortality and infectivity tests on Giant Cavendish bananas. Purified extracts of several *Penicillium* spp. (*P. oxalicum*, *P. anaticum*) and *Aspergillus niger* showed high nematicidal activity. This search for biological control agents has resulted in the so-called BIOCON Technology in which liquid and powder formulations containing *Paecilomyces lilacinus* and *P. oxalicum* are successfully used to control nematodes, including *Meloidogyne* spp. on banana. Also arbuscular fungi are being investigated as biological control agents. Under greenhouse conditions, inoculation of micropropagated bananas of the cultivar Grand Naine (Cavendish subgroup), with two *Glomus mosseae* isolates suppressed root galling and nematode build-up in the roots of *M. incognita*. Inoculation of the same banana cultivar with *Glomus intraradices* did not affect the build-up of *M. incognita* in the roots but increased plant growth by enhancing plant nutrition.

Banana roots infected with swollen root-knot nematode females.