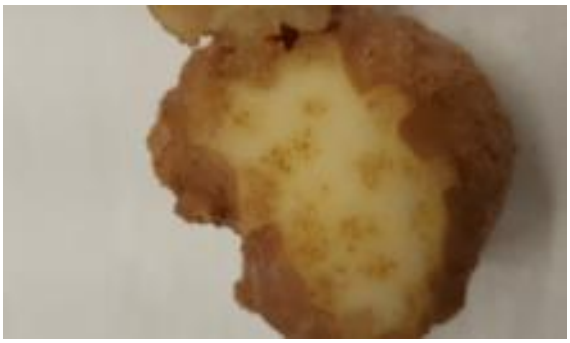
EPPO Datasheet: *Meloidogyne enterolobii*

Last updated: 2020-09-11

IDENTITY

Preferred name: *Meloidogyne enterolobii*
Authority: Yang & Eisenback
Taxonomic position: Animalia: Nematoda: Chromadorea: Rhabditida: Meloidogynidae
Other scientific names: *Meloidogyne mayaguensis* Rammah & Hirschmann
Common names: guava root-knot nematode
view more common names online...
EPPO Categorization: A2 list
view more categorizations online...
EU Categorization: Quarantine pest ((EU) 2019/2072 Annex II A)
EPPO Code: MELGMY



more photos...

Notes on taxonomy and nomenclature

Meloidogyne enterolobii was described by Yang & Eisenback (1983) from roots of pacara earpod trees (*Enterolobium contortisiliquum*), on Hainan Island in China. In 1988 Rammah and Hirschmann described *M. mayaguensis* from roots of eggplant (*Solanum melongen*a) from Puerto Rico and indicated that this new species 'superficially resembles *M. enterolobii*' but shows 'several distinct morphological features and a unique malate dehydrogenase pattern (N3c)'. Karssen *et al.* (2012) re-studied the holo- and paratypes of both species and confirmed *M. mayaguensis* as a junior synonym for *M. enterolobii*.

HOSTS

The root-knot nematode *Meloidogyne enterolobii* is polyphagous and has many host plants including cultivated crops and weeds. It infests herbaceous as well as woody plants. The main hosts of commercial importance include *Coffea arabica* (coffee) [it is noted that while coffee can be susceptible to some populations of *M. enterolobii*, it has been reported as resistant to other ones (see details in the control paragraph)], *Gossypium hirsutum* (cotton), *Cucumis sativus* (cucumber), *Solanum melongena* (eggplant), *Psidium guajava* (guava), *Carica papaya* (papaya), *Capsicum annuum* (pepper), *Solanum tuberosum* (potato), *Glycine max* (soybean), *Ipomoea batatas* (sweet potato), *Nicotiana tabacum* (tobacco), *Solanum lycopersicum* (tomato), and *Citrullus lanatus* (watermelon). For *G. hirsutum*, Brito *et al.* (2004) reported that four Florida isolates of *M. enterolobii* reproduced on this host, which confirmed the original description by Yang & Eisenback (1983). Recently this nematode was found infesting cotton under field conditions in North Carolina, USA (Ye *et al.*, 2013) and Brazil (Galbieri *et al.*, 2020). While *C. papaya* has been found infested by *M. enterolobii* in the field (Lima *et al.*, 2003; Souza *et al.*, 2006; Brito *et al.*, 2008), the cultivars Formosa and Papaya when inoculated with a nematode population collected from *P. guajava* were reported as non-hosts (Freitas *et al.*, 2017). The host status is determined by calculating the reproductive factor RF (RF = final population (Pf) / initial population (Pi); RF ? 1, good host; 0.1< RF <1.0, poor host; RF ? 0.1, non-host) (Sasser *et al.*, 1984). It is expected that many more plant species will be hosts of *M. enterolobii* than currently known, since this is the case with other polyphagous *Meloidogyne* spp.

Some crops have been reported as non-hosts or poor hosts for *M. enterolobii*, including *Euterpe oleracea* (Assai palm), *Persea americana* (avocado), *Brassica oleracea* (cabbage), *Anacardium occidentale* (cashew), *Annona cherimola* (cherimoya) *Cocos nucifera* (coconut), *Allium sativum* (garlic), *Citrus* × *paradisi* (grapefruit), *Citrus limonia* (lemon 'Cravo'), *Citrus volkameriana* (lemon 'Volkameriano), *Zea mays* subsp. *mays* (maize), *Mangifera indica* (mango), *Olea europaea* (olive), most of the *Passiflora* spp. (passion fruit), *Arachis hypogaea* (peanut), *Citrus reticulata* (tangerine 'Cleopatra'), *Citrus trifoliata* (trifoliata), *Citrus* × *aurantium* (sour orange), *Averrhoa carambola* (starfruit), *Fragaria* × *ananassa* (strawberry), *Citrus sunki* (tangerine 'Sunki'), and *Allium fistulosum* (Welsh onion) (Rammah & Hirschmann, 1988; Guimaraes *et al.*, 2003; Rodriguez *et al.*, 2003; Brito *et al.*, 2004;

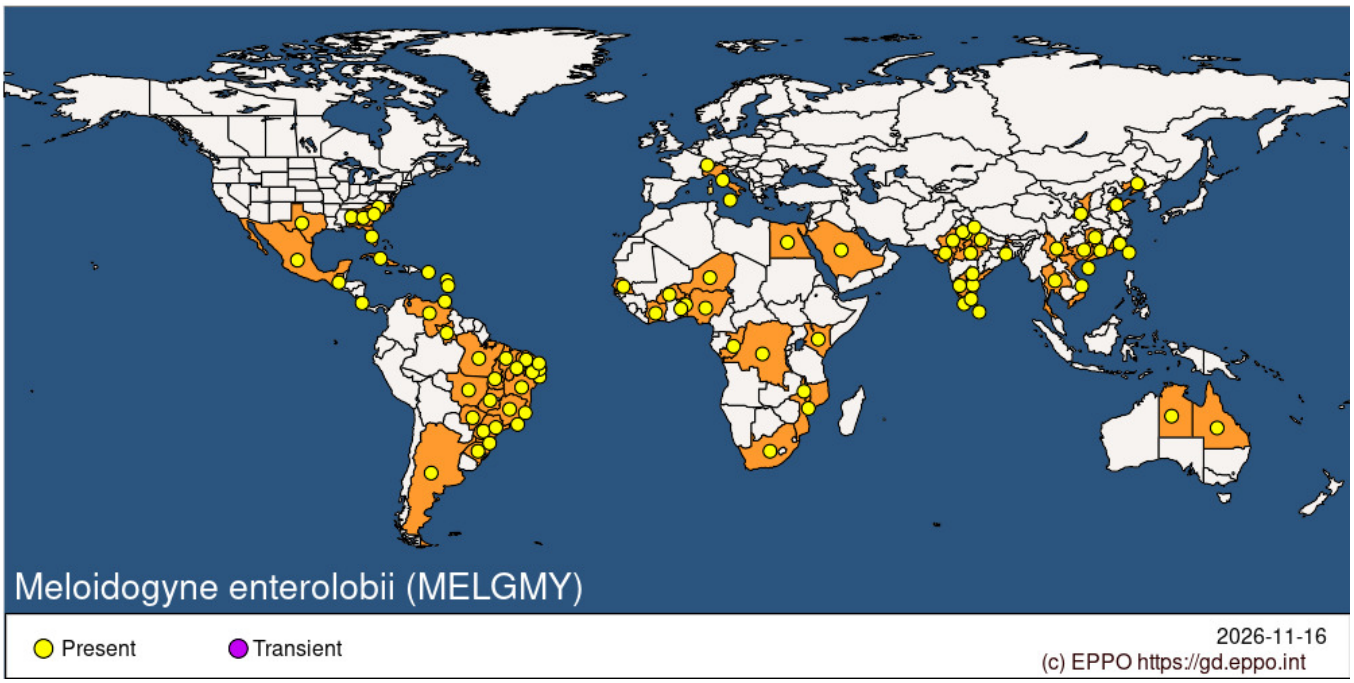
Bitencourt & Silva, 2010; Dias *et al.*, 2010a; Rosa *et al.*, 2012; Freitas *et al*., 2014; 2017).

Host list: *Abelmoschus esculentus, Acalypha australis, Ajuga reptans, Allium cepa, Alocasia sp., Alysicarpus vaginalis, Amaranthus hybridus, Amaranthus tricolor, Angelonia angustifolia, Antirrhinum majus, Apium graveolens , Artocarpus heterophyllus, Basella alba, Beta vulgaris, Bidens pilosa, Brachychiton sp., Brassica oleracea var. botrytis, Brugmansia hybrids, Brugmansia, Buddleja davidii, Caladium sp., Callistemon sp., Camellia oleifera, Cannabis sativa, Capsicum annuum, Carica papaya, Caryopteris x clandonensis, Celosia argentea, Centrosema sp., Cereus fernambucensis, Cereus hildmannianus, Chrysalidocarpus lutescens, Citrullus lanatus, Citrus maxima, Coffea arabica, Coleus scutellarioides, Corchorus olitorius, Coriandrum sativum, Cucumis melo, Cucumis sativus, Cucurbita moschata, Cucurbita pepo, Curcuma longa, Daucus carota, Dioscorea rotundata, Elaeocarpus decipiens, Enterolobium contortisiliquum, Epipremnum sp., Erechtites hieraciifolius, Eryngium foetidum, Euonymus sp., Euphorbia heterophylla var. cyathophora, Euphorbia prostrata, Euphorbia pulcherrima, Euphorbia punicea, Euphorbia tirucalli, Ficus sp., Gardenia jasminoides, Glycine max, Gossypium hirsutum, Hosta plantaginea, Hoya carnosa, Hydrocotyle bonariensis, Ipomoea batatas, Ixora chinensis, Jatropha urens, Lagerstroemia indica, Lampranthus sp., Lantana camara, Lantana montevidensis, Ligustrum sp., Liriope muscari, Liriope sp., Luffa aegyptiaca, Malpighia emarginata, Malpighia glabra, Manihot esculenta, Maranta arundinacea, Melaleuca citrina, Melaleuca linearis, Melaleuca viminalis, Morinda citrifolia, Morus alba, Morus celtidifolia, Morus nigra, Morus, Musa sp., Myrica cerifera, Nicotiana tabacum, Ocimum basilicum, Oeceoclades maculata, Ormosia hosiei, Passiflora edulis, Passiflora mucronata, Paulownia elongata, Pentas lanceolata, Perilla frutescens var. crispa, Phaseolus vulgaris, Physalis peruviana, Pithecellobium dulce, Platostoma palustre, Primulina tabacum, Psidium guajava, Rosa sp., Rotheca myricoides, Sageretia thea, Sageretia, Salix x pendulina f. salamonii, Samanea saman, Selenicereus costaricensis, Selenicereus megalanthus, Selenicereus undatus, Selenicereus, Senna alata, Senna occidentalis, Siraitia grosvenorii, Solandra maxima, Solanum americanum, Solanum lycopersicum, Solanum macrocarpon, Solanum melongena, Solanum nigrum, Solanum pseudocapsicum, Solanum quitoense, Solanum scabrum, Solanum tuberosum, Stenocereus queretaroensis, Syngonium sp., Syzygium aromaticum, Syzygium, Talinum fruticosum, Tecoma capensis, Thunbergia sp., Tibouchina sp., Trigonella balansae, Ulmus parvifolia, Zelkova serrata, Zelkova, Zingiber officinale, Ziziphus jujuba*

GEOGRAPHICAL DISTRIBUTION

M. enterolobii has been reported from several countries in North, Central and South America, Africa and Asia. Its present distribution in warmer climates suggests that this species will not survive outside greenhouses in northern countries of Europe, but it might be able to establish in the Mediterranean region. For Europe *M. enterolobii* was first recorded in a greenhouse in France (Blok *et al.*, 2002), but the pest is no longer present. It has also been reported from two greenhouses in Switzerland associated with severe damage on tomato and cucumber (Kiewnick *et al.*, 2008) and Portugal from some private gardens on *Cereus hildmannianus, Lampranthus* sp., *Physalis peruviana* and *Callistemon* sp. detected during a survey (Santos *et al.*, 2019).

M. enterolobii has been intercepted in EPPO countries such as the Netherlands, Germany and the UK several times in imported plant material (e.g. Cactaceae, *Syngonium* sp., *Ficus* sp., *Ligustrum* sp., *Brachychiton* sp., *Rosa* sp.) from Asia, South America and Africa.



EPPO Region: Italy (mainland, Sicilia), Switzerland
Africa: Benin, Burkina Faso, Congo, Congo, The Democratic Republic of the, Cote d'Ivoire, Egypt, Kenya, Malawi, Mozambique, Niger, Nigeria, Senegal, South Africa, Togo
Asia: China (Fujian, Guangdong, Guangxi, Hainan, Hunan, Liaoning, Shaanxi, Shandong, Yunnan), India (Andhra Pradesh, Delhi, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Rajasthan, Tamil Nadu, Telangana, Uttarakhand, Uttar Pradesh, West Bengal), Saudi Arabia, Sri Lanka, Taiwan, Thailand, Vietnam
North America: Mexico, United States of America (Alabama, Florida, Georgia, North Carolina, South Carolina, Texas)
Central America and Caribbean: Costa Rica, Cuba, Guadeloupe, Guatemala, Martinique, Puerto Rico, Trinidad and Tobago
South America: Argentina, Brazil (Alagoas, Bahia, Ceara, Espirito Santo, Goias, Maranhao, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Para, Paraiba, Parana, Pernambuco, Piaui, Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, Roraima, Santa Catarina, Sao Paulo, Tocantins), Venezuela
Oceania: Australia (Northern Territory, Queensland)

BIOLOGY

M. enterolobii like other species of root-knot nematodes, is a sedentary endoparasite. Second-stage juveniles (J2) hatch from eggs in the soil or root debris and migrate towards the root tip of candidate host plants. Using their stylet or wounds, juveniles enter the unsuberized epidermal cells near the root tip and migrate within the cortical tissue until they initiate a permanent feeding site in close proximity to the vascular tissue. Juveniles soon lose their mobility and become sedentary. At the same time, feeding of the J2 on root cells induce those cells to differentiate into multinucleate nursing cells, so-called giant cells. The surrounding tissue starts to divide giving rise to a typical root gall or root-knot. During their further development juveniles swell to become sausage- shaped and undergo three moults before they reach adult stages. Adult females are pear-shaped and found almost completely embedded in the host tissue. Eggs are laid by the female in a gelatinous sac near the root surface (Moens *et al*., 2009). Adult males are vermiform and found free in the rhizosphere or near the protruding body of the female. As for other *Meloidogyne* species, reproduction is nearly almost always parthenogenetic. The life cycle of *M. enterolobii* takes 4–5 weeks under favorable conditions and it has been reported that on *I. batatas* females produce around 460–500 eggs per egg mass (Brito *et al*., 2020).

DETECTION AND IDENTIFICATION

Symptoms

M. enterolobii affects growth, yield, lifespan and tolerance to environmental stresses of infested plants. Typical above-ground symptoms include stunted growth, wilting and leaf yellowing. Typical root galls, which can be large and numerous, are found below-ground (Cetintas *et al.*, 2007). Overall, damage due to *M. enterolobii* may consist of reduced quantity and quality of yield. Plant infection with secondary plant pathogens may be enhanced following *M. enterolobii* infestation, as is described for *Fusarium solani* on guava (Gomes *et al.*, 2011).

Morphology

Second-stage juveniles are vermiform, annulated, tapering at both ends, 250–700 µm long, 12–18 µm wide, tail length 15–100 µm and hyaline tail part 5–30 µm in length (Yang & Eisenback, 1983; Rammah & Hirschmann, 1988). Females are characteristically globular to pear-shaped, pearly-white and sedentary. Their body is annulated, 400– 1300 µm long, 300–700 µm wide and shows lateral fields each with 4 incisures. The stylet is dorsally curved, 10– 25 µm long, with rounded to ovoid stylet knobs, set off to sloping posteriorly. The perineal pattern is round to ovoid; the arch is moderately high to high and usually rounded. The vermiform males are annulated, slightly tapering anteriorly, bluntly rounded posteriorly, 700–2000 µm long and 25–45 µm wide. The stylet is 13–30 µm long, with stylet knobs, variable in shape.

M. enterolobii closely resembles other tropical root-knot nematodes such as *M. incognita*, *M. arenaria* and *M. javanica*. In general, it can be separated from other species within the genus by perineal pattern shape, male and female stylet morphology; morphology of the male; body length and morphology of the lip region, as well as tail and hyaline tail part in second-stage juveniles according to EPPO Standard PM 7/103 (EPPO, 2016). Among the other *Meloidogyne* species which are on the EPPO lists of pests recommended for regulation, *M. chitwoodi* and *M. fallax*, are usually not associated with *M. enterolobii* and can also be clearly distinguished by their demarcated hyaline tail end.

Detection and inspection methods

The presence of *M. enterolobii* in infested soil and planting material can be determined by sampling of suspected material and subsequent extraction of second-stage juveniles using standard methods described in the EPPO Standard PM 7/119 on Nematode Extraction (EPPO, 2013a). Root samples should also be collected, it is particularly necessary to extract females to aid species identification. Microscopic examination at 800–1000 times magnification is necessary for correct identification of the nematode species. Presence of males can assist in identification. However, as morphological characters of *M. enterolobii* are often similar to other *Meloidogyne* species, identification to species level is usually based on a combination of morphological/morphometrical characters and biochemical or molecular methods (isozyme electrophoresis, PCR or real-time PCR). For details see the EPPO Diagnostic Protocol (EPPO, 2016). The real-time-PCR protocol recommended for *M. enterolobii* identification has also been used successfully outside of the EPPO region by another Regulatory Agency to identify this nematode species on both regulatory and diagnostic samples (Moore *et al.*, 2020a; 2020b).

Nematode populations in the soil tend to decline in the absence of a host (McSorley, 1998) and they reproduce better on good host. Therefore, detection of the nematodes through field inspection and soil sampling is more sensitive if done as close as possible to the time of harvest of a host crop, targeting particularly susceptible plants. It is imperative that samples collected are representative of the entire sampled field. When nematode densities are believed to be extremely low, a larger number of cores that comprise a sample may be needed, this is particularly important for samples taken for regulatory purposes.

PATHWAYS FOR MOVEMENT

As is the case for other plant-parasitic nematodes *M. enterolobii*'s own movement is limited at most to a few tens of centimetres in the soil. The main pathways for nematode dissemination are via infested planting material and soil, such as traded host plants for planting (including cuttings) with roots, non-host plants for planting with soil attached, other traded soil bearing products such as potatoes, soil attached to equipment and machinery, travelers, soil as such and irrigation water (EPPO, 2010).

PEST SIGNIFICANCE

Economic impact

M. enterolobii is considered as very damaging due to its virulence (Fargette 1987; Carneiro *et al*., 2006; Brito *et al*., 2007b; Cetintas *et al*., 2008; Kiewnick *et al*., 2009; Pinheiro *et al*., 2015), wide host range, high reproduction rate and induction of large galls (Castagnone-Sereno, 2012). Severe damage caused by *M. enterolobii* has been reported for several crops, including *Psidium guajava* in many parts of the world, particularly in Brazil, where it is widespread and reported to cause approximately 61 million USD in total economic loss and 3703 full - time jobs losses, and even plant death (Pereira *et al.*, 2009); *S. lycopersicum* with yield loss up to 65% (Cetintas *et al*., 2007); *C. sativus* (Kiewnick *et al.*, 2008), *C. lanatus* (Ramirez-Suarez *et al.*, 2014), and *C. annuum* (Carneiro *et al*., 2006; Pinheiro *et al*., 2015). Most recently severe outbreaks of *M. enterolobii* have been observed in the major sweet potato producing states in the USA (Anonymous, 2017; Anonymous, 2018a; 2018b; Rutter *et al*., 2019). This nematode was reported causing severe yield and root quality reduction, and in at least one case, total crop loss (Anonymous, 2017). As a result, some states have imposed external quarantine for this nematode species. Compared with other root-knot nematode species, *M. enterolobii* displays virulence against several sources of root-knot nematode-resistance genes, which constitutes a challenge for its management particularly when dealing with a mixture of root-knot nematode species. For example, *M. enterolobii* develops on crop genotypes carrying resistance to the major species of *Meloidogyne*, including resistant cotton, sweet potato, tomatoes (*Mi-1*gene), potato (*Mh* gene), soybean (*Mir1* gene), bell pepper (*N* gene), sweet pepper (*Tabasco* gene) and cowpea (*Rk* gene) (summarized in Castagnone-Sereno, 2012). Similarly, *M. enterolobii* has been found inducing severe root galling, plant defoliation, yield losses and reduction of fruit quality on *Capsicum* rootstock 'Snooker' carrying the Me1 and Me3/Me7 genes (Pinheiro et al., 2015) in a commercial plastic house. In countries where *M. enterolobii* is regulated, traded plants and plant products infested with *M. enterolobii* may need to be destroyed.

Control

General management strategies for root-knot nematodes have been reviewed by Coyne *et al.* (2009) and Nyczepir & Thomas (2009). Taking into account the banning of most chemical nematicides, resistance, crop rotation and the use of non-host crops or black fallow, and good weed control are the most efficient methods for reducing *M. enterolobii* populations. Unfortunately, the list of non-host plants is limited, including cabbage, garlic, grapefruit, maize, peanut, sour orange and Welsh onion. Brito *et al.* (2007a) reported that two carrot cultivars and *Brassica oleracea* (collard) allowed very little or no nematode reproduction. Of various selections of *Phaseolus vulgaris*, *P. lunatus*, *Vigna radiata*, *V. unguiculata* and *Canavalia ensiformis* being tested for their susceptibility to *M. enterolobii* only *P. vulgaris* cv. Alabama was resistant (Crozzoli *et al.*, 2011). Attempts to identify sources of resistance to this nematode species in tomato and pepper germplasms have failed. For instance, all 101 cultivated and wild tomato genotypes tested were susceptible (Silva *et al*., 2019), and none of the 24 pepper accessions were resistant (Soares *et al*., 2018). However, significant progress has been made and some resistance to *M. enterolobii* has been identified on sweet potato (Schwarz *et al.*, 2020). Squash and lettuce showed some resistance towards *M. enterolobii* (Bitencourt & Silva, 2010) and eight genotypes of soybean turned out to be tolerant to *M. enterolobii* while 60 genotypes were susceptible (Dias *et al.*, 2010b). Compared to annual crops, more sources of resistance towards *M. enterolobii* have been reported for perennial crops such as the *R Mia* resistance gene in *Prunus persica* (peach) rootstocks (Claverie *et al.*, 2004; Nyczepir *et al.*, 2008), the *Ma* gene in *Prunus cerasifera* (Myrobalan plum) (Rubio-Cabetas *et al.*, 1999) and a newly detected resistance in the wild *Psidium guineense* was successfully used to develop a hybrid guava rootstock, 'BRS Guaraçá', which was released in 2018 (Castro, 2019; Costa *et al*., 2012; Souza *et al*., 2018). Although coffee has been reported as a host for *M. enterolobii* (Decker & Rodriguez Fuentes, 1989), all seven coffee cultivars tested with a nematode population initially isolated from guava were resistant (Alves *et al.*, 2009). However, three out of seven coffee cultivars tested with another population originally collected from coffee in Costa Rica (Muniz *et al*., 2009) proved to be susceptible. Further studies are needed to clarify the genetic variability, if any, among populations of this nematode species collected from different host plants around the world.

Phytosanitary risk

With increased global trade, special attention should be given to the importation of plants for planting (e.g. seedlings and slips), plant products and soil from areas where *M. enterolobii* occurs. Reports of *M. enterolobii* in glasshouses in the EPPO region clearly demonstrate that it has the potential to enter Europe (Blok *et al.*, 2002; Kiewnick *et al.*, 2008). It also has been detected on several occasions in the USA during routine regulatory sampling at ornamental

nurseries in Central and South Florida which has a comparable climate to Southern Europe (Brito *et al*., 2002; Brito *et al*., 2010, Han *et al.*, 2012; Moore *et al*., 2020a; 2020b). It is very likely that this species can survive in the warmer parts of the EPPO region and in glasshouses throughout the EPPO region. In addition, this species was detected on roses (plants for planting) originating from China (see EPPO RS 2008/107), thus suggesting that it can also survive slightly cooler temperatures. As mentioned above *M. enterolobii* is highly virulent and produces more root galls than other root-knot nematodes, as the correlation between root galling and yield loss is well known (Ploeg & Phillips, 2001; Kim & Ferris, 2002), it is expected that *M. enterolobii* will cause yield losses similar to *M. incognita* and *M. javanica,* which are well established in large parts of the EPPO region. Once root-knot nematodes have been introduced, it is in general difficult to control or eradicate them.

PHYTOSANITARY MEASURES

Suggested phytosanitary measures are specified in the PRA performed by EPPO (EPPO, 2010); they are as follows. Rooted host plants for planting (with or without soil), non-host plants for planting with soil attached and plant products with soil attached should come from a pest free area, a pest free place of production or should be produced under protected cultivation. Alternatively, soil from non-host plants for planting or plant products should be removed. Soil as such should originate from a pest free area or a pest free place of production. Used machinery, equipment, vehicles, and passengers' shoes should be cleaned. Publicity would allow to enhance public awareness on *M. enterolobii* when travelling.

Measures similar to those recommended by EPPO to contain or eradicate *Meloidogyne chitwoodi* and *M. fallax* (EPPO, 2013b) would be relevant.

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