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This PRA document was modified in 2021 to clarify the phytosanitary measures recommended

European and Mediterranean Plant Protection Organisation
Organisation Européenne et Méditerranéenne pour la Protection des Plantes

Guidelines on Pest Risk Analysis
Lignes directrices pour l'analyse du risque phytosanitaire

Decision-support scheme for quarantine pests Version N°3

PEST RISK ANALYSIS FOR *Meloidogyne enterolobii*

Pest risk analysts:			Expert Working group for PRA for *M. enterolobii* Ms Anthoine Géraldine, French National Plant Health Laboratory- Nematology Unit (FR) Ms Brito Janete, Florida Department of Agriculture and Consumer Service, Division of Plant Industry (US) Mr Guitian Castrillon Jose Maria, Tecnologias y Servicios Agrarios, S. A. – TRAGSATEC (ES) Ms Ilieva Zhenya, Plant Protection Institute (BG) Mr Karssen Gerrit, Plant Protection Service (NL) Mr Kiewnick Sebastian, Agroscope Changins-Wädenswil ACW, Research Station ACW, Plant Protection Zoology/Nematology (CH) Mr Niere Björn, Julius Kühn-Institut (DE) Mr Steffek Robert, Austrian Agency for Health and Food Safety (AGES), Institute for Plant Health (AT)-(core member) Core member consultation in 2009-12 Panel on Phytosanitary measures 2010-02-16/19.

Stage 1: Initiation

1 Give the reason for performing the PRA	Identification of a single pest	The NPPOs of the Netherlands and Germany have detected *M. enterolobii* (syn. *M. mayaguensis*) in imported plant material. In 2008, an outbreak was detected in Switzerland. Within the tropical root-knot nematodes, this species can be considered as one of the most damaging species and several economically important species are host plants. Resistance to other tropical root-knot nematodes of important crop cultivars, such as the *Mi-1* gene carrying tomato cultivars, is not effective against *M. enterolobii*. The Working Party on Phytosanitary Regulations recommended that a PRA should be performed.

2 Name of the pest	*Meloidogyne enterolobii*	The pest of concern is *Meloidogyne enterolobii* Yang & Eisenback, 1983 (Meloidogynidae, Nematoda). *Meloidogyne mayaguensis* Rammah & Hirschmann, 1988 is a junior synonym of *M. enterolobii* (Karssen, in preparation; see also Xu *et al*., 2004).
2 Taxonomic position		Taxonomic Tree Domain: Eukaryota Kingdom: Metazoa Phylum: Nematoda Family: Meloidogynidae Genus: *Meloidogyne* Species: *enterolobii*
3 PRA area		The PRA area is the EPPO region (see map www.eppo.org).
4 Does a relevant earlier PRA exist?	yes	A Dutch PRA was performed (Karssen *et al*., 2009) and forms the basis of this regional PRA.
5 Is the earlier PRA still entirely valid, or only partly valid (out of date, applied in different circumstances, for a similar but distinct pest, for another area with similar conditions)?	not entirely valid	The PRA has been performed mainly for the Netherlands .Where applicable, relevant information from the Dutch PRA has been used in this PRA.
6 Specify the host plant species (for pests directly affecting plants) or suitable habitats (for non parasitic plants) present in the PRA area.		The host range of *M. enterolobii* includes a large number of horticultural and agricultural crops (Brito *et al*., 2004a b & c) (see Appendix 1). It is expected that many more plant species will be hosts of *M. enterolobii* than currently known, since this is the case also with other, closely related root knot nematodes. Host plant research has mainly been carried out in (sub) tropical countries. Consequently, many of the known host plants are of no or only minor commercial importance for the EPPO region nevertheless some of the host plants are major crops in the EPPO region (e.g. tomato) or major ornamental plants such as *Rosa* sp. Tropical root knot nematodes usually have a wide host range. The EWG considered that the host list for *M. enterolobii* is likely to be similar to that of *M. incognita*. *M. incognita* has a very wide host range, with nearly every higher *planta* known to be a host (Jepson, 1987) and including more than 200 plant genera (Krishnappa, 1985 referred to in CABI, 2007). Research would be needed to obtain more knowledge about the host plants of *M. enterolobii* among commercially important crops in the EPPO region. **Uncertainty:** *M. enterolobii* has a wide host range but further tests are needed for Monocotyledon plants.
7 Specify the pest distribution		**EPPO region:** France (reported once from Concarneau, Bretagne region), and Switzerland. *Note*: in the Netherlands, *M. enterolobii* has been intercepted approximately 10 times (from 1991 to 2007) in imported plant material from Asia, South America and Africa. Findings before 2007 could only be confirmed in the second half of 2007 when full information needed for reliable identification became available. It has been intercepted once in Germany (but on a large volume of plants for planting). It has also been detected on *Vitis* spp. but no further information on this finding is available consequently the pest is not considered as present in the Netherlands.

		Africa: Burkina Faso, Ivory Coast, Malawi, Senegal, South Africa, Togo. **Asia**: China (Hainan), Vietnam. **North America**: USA (Florida, first reported in 2002 on ornamentals and then in a commercial tomato field and a tropical fruit nursery). **Central America and Caribbean**: Cuba, Guatemala, Martinique, Guadeloupe, Puerto Rico, Trinidad and Tobago. **South America**: Brazil (Bahia, Ceara, Maranhao, Minais Gerais, Parana, Pernambuco, Piaui, Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, Sao Paulo), Venezuela. A table indicating references for the pest distribution is presented in Appendix 2.

Stage 2: Pest Risk Assessment - Section A : Pest categorization

8 Does the name you have given for the organism correspond to a single taxonomic entity which can be adequately distinguished from other entities of the same rank?	yes	*M. enterolobii* is a single taxonomic entity. It is broadly accepted among nematologists as a senior synonym of *M. mayaguensis.* It can be identified based on several characteristic features. These features (morphological, isozyme and DNA information) are described by Brito *et al*., 2004c. The identification of the tropical root-knot nematodes is relatively complex and only recently has the full information needed for reliable species identification become available for some of them (including *M. enterolobii*) (Xu *et al.* 2004, Randig et al., 2009) *M. enterolobii* may have been misidentified as *M. arenaria* or *M. incognita*.
10 Is the organism in its area of current distribution a known pest (or vector of a pest) of plants or plant products?	yes (the organism is considered to be a pest)	All available literature refers to *M. enterolobii* as a highly virulent and damaging nematode species, when compared to the other tropical root-knot nematodes. Brito *et al*. (2004b) state that *M. enterolobii* is highly virulent to many vegetables. *M. enterolobii* induces relatively large galls on roots and can cause significant damage to a large number of vegetable and field crops (Cetintas *et al.*, 2007; Lima *et al.*, 2003; Willers 1997b). Significant yield losses are observed in Switzerland (Kiewnick *et al.*, 2008) Also the virulence displayed by *M. enterolobii* against several sources of resistance to *M. incognita*, *M. javanica* and *M. arenaria* makes it a potential threat (Blok *et al*., 2002; Berthou et al., 2003; Brito *et al*., 2004b).
12 Does the pest occur in the PRA area?	yes	*M. enterolobii* has been reported in two countries of the EPPO region South Brittany, France (Blok *et al*., 2002): It was detected in a tomato crop under a plastic tunnel. The site was used for growing vegetable (tomato, cucumbers, beans, eggplants, potato and pepper) and located in an area where ornamental plants are grown (e.g. geranium, petunia, begonia etc). The seedlings used in this site originate from nurseries in Brittany. Although reported in 2002 the first detection dates back to the late 70s (Anthoine pers. comm., 2009). Soil disinfectants were applied (once methyl bromide and once metham sodium) during the 80s, but the nematodes survived. No plants or soil exchanges occurred with surrounding farms. The field where the nematode was detected was sampled again in 2008 (from eggplant roots) and could still be detected. Switzerland (Kiewnick *et al.*, 2008)

		It has also been reported from two greenhouses in Switzerland on cucumber and tomato. It is still present in these two greenhouses (Kiewnick *et al.*, 2008). *Note* It was found on a *Vitis* sp. plant sent to the NPPO of the Netherlands in 2007. The origin of the plant was unknown. It has been intercepted in the Netherlands on a consignment of *Brachychiton* sp. plants imported from Israel. The EPPO Secretariat has contacted the Israeli NPPO which commented that the pest has not been detected in Israel (Opatowski pers. comm., 2009) based on surveys carried out for root nematodes.
13 Is the pest widely distributed in the PRA area?	not widely distributed	No other records of *M. enterolobii* (still) being present in (parts of) the EPPO region apart from those mentioned in 12 are known , but the presence of the nematode cannot be excluded particularly since no extensive surveys have been carried out for *M. enterolobii* and the pest is difficult to identify (see question 8).
14 Does at least one host-plant species (for pests directly affecting plants) or one suitable habitat (for non parasitic plants) occur in the PRA area (outdoors, in protected cultivation or both)?	yes	Several hosts of *M. enterolobii* are cultivated in the PRA area, such as tomato (*Lycopersicon esculentum*) and several *Solanum* species. They are cultivated both outdoors and in greenhouses. Hosts include also tree species such as *Acacia* spp. (Duponnois *et al*., 1997), and ornamentals including roses (on imported consignments NPPO of Germany and the Netherlands) and cactus species (on imported consignments NPPO of the Netherlands).
16 Does the known area of current distribution of the pest include ecoclimatic conditions comparable with those of the PRA area or sufficiently similar for the pest to survive and thrive (consider also protected conditions)?	yes	The present distribution (Africa, USA (Florida), Central and South America, China and Vietnam) suggests that this species will survive in the Mediterranean region, where some tropical *Meloidogyne* species already occur. *M. enterolobii* has been detected under protected conditions (plastic tunnel) in France (Blok *et al.*, 2002) and in glasshouses in Switzerland (Kiewnick *et al.*, 2008. Other tropical root knot nematodes occur under protected conditions in the EPPO region. This statement is also supported by a simple climate comparison on the world map of the Köppen-Geiger climate classification (see Appendix 3.
17 With specific reference to the plant(s) or habitats which occur(s) in the PRA area, and the damage or loss caused by the pest in its area of current distribution, could the pest by itself, or acting as a vector, cause significant damage or loss to plants or other negative economic impacts (on the environment, on society, on export markets) through the effect on plant health in the PRA area?	yes	Host plants on which damage is recorded are present in the EPPO region (e.g. tomato, cucumber, roses…). Effects on plant health are likely. Damage is recorded in Switzerland.
18 Summarize the main elements leading to this conclusion.		*Meloidogyne enterolobii* is a known pest. Host plants and suitable eco climatic conditions are present in the PRA area.

Stage 2: Pest Risk Assessment - Section B : Probability of entry of a pest

1.1 Consider all relevant pathways and list them		*M. enterolobii* is most likely to enter the PRA area in infested plant material or infested soil. Since *M. enterolobii* only feeds on root tissue, plant material is likely to be infested only if roots are present. As with other *Meloidogyne* spp., infested soil may be associated with some commodities (potted plants) and international transport of equipment and machinery (Davis & Venette, 2004a and 2004b). The EWG considered the following possible pathways; Host plants for planting (including cuttings) with roots (with or without soil); Non host plants for planting with soil attached; Plant products that may have soil attached (such as tubers bulbs or rhizomes); Soil attached to equipment and machinery; Travellers; Soil as such. **The most relevant traded pathway was considered to be host plants or cuttings with roots (with or without soil) and traded non host plants with soil attached**. The EWG noted that the importation of plants for planting of *Solanaceous* species is prohibited from non European and Mediterranean countries for the 29 out of 50 EPPO member countries (EU, 2000). The most likely pathways are ornamental plants. As information on trade is not specific enough (no detailed information at species level nor distinction between plants with or without soil attached), the pathways of host plants or cuttings with roots (with or without soil) and the pathway of non host plants with soil attached have been studied together. When relevant, differences have been noted in the explanatory text. Other pathways (probability of entry not studied in detail) *Plant products that may have soil attached (such as tubers, bulbs or rhizomes)* Import of tubers of *Solanum tuberosum* from countries outside the region is restricted in most EPPO countries. *Ipomea batatas* is a host plant of *M. enterolobii* but trade is very limited. Soil attached to bulbs rhizomes may contain the nematode. A detailed study of the probability of entry could not be performed during the EWG but the risk management part was performed after the meeting. *Soil as such* Importation of soil as such is prohibited in most EPPO countries. As mentioned above the pest can enter with soil but it is not possible to fully evaluate the probability of entry due to lack of data regarding trade. Consequently, a detailed study of the probability of entry has not been performed but as it is a possible pathway measures are considered in the section on risk management.

		Soil attached to equipment and machinery, travellers A detailed study of the probability of entry with these pathways has not been performed due to lack of data but general measures are considered in the section on risk management. ***Impossible pathways*** The following plant parts do not carry *M. enterolobii* in trade: bark, wood, fruits, flowers, leaves, above-ground stems without roots, seeds and grains.
1.2 Estimate the number of relevant pathways, of different commodities, from different origins, to different end uses.	moderate number low	With regards to the current area of distribution of the nematode, although few plants / plant products are imported from Cuba, Puerto Rico, Trinidad and Tobago, Martinique and Guadeloupe, several plant species with roots are imported from the remaining area of distribution presently. These include ***Rosa*** spp., *Schefflera* spp., *Sansevieria* spp., (pseudo-) bonsai (***Ficus***, ***Ligustrum***, *Sageretia*, *Serissa*, *Zelkova*, *Carmona*, etc) and several (non-dwarfed) tree species. Overall, we estimate a moderate number of pathways. (known host plants are in bold)

<table>
<tr><td>1.4 Pathway :</td><td></td><td>Host plants for planting (including cuttings) with roots (with or without soil) and non-host plants for planting with soil attached</td></tr>
<tr><td>1.4a Is this pathway a commodity pathway ?</td><td>yes</td><td></td></tr>
<tr><td>1.4b How likely is the pest to be associated with the pathway at origin taking into account factors such as the occurrence of suitable life stages of the pest, the period of the year?</td><td>moderately likely
medium</td><td><i>M. enterolobii</i> is an endoparasitic nematode. If a host plant is planted in infested growing media, juveniles will enter the roots and consequently the pest is likely be associated with the pathways. Regarding non host plants, the pest can be present in the growing media associated with these plants. The fact that the NPPO of the Netherlands intercepted ornamental plants with <i>M. enterolobii</i> indicates that some nurseries within Asia and Africa are likely to be infested with <i>M. enterolobii.</i> The number of known interceptions is low. However, low infestation levels in imported consignments can easily be overlooked during inspection and the number of interceptions may underestimate the percentage of infested consignments. In addition, morphological identification of <i>Meloidogyne</i> species is difficult. In recent years, EU member states regularly reported interceptions of <i>Meloidogyne</i> sp. (EUROPHYT) which were not identified up to species level. These <i>Meloidogyne</i> sp. might have been <i>M. enterolobii</i>.

Table 1. Findings/interceptions of <i>Meloidogyne enterolobii</i> by the NPPO of the Netherlands
<table>
<tr><th>Year</th><th>Plant species</th><th>Origin</th></tr>
<tr><td>1991(1)</td><td><i>Cactus</i> sp.</td><td>South Africa</td></tr>
<tr><td>1993 + 1994(1)</td><td><i>Syngonium</i> sp.</td><td>Togo</td></tr>
<tr><td>1999(1)</td><td><i>Ficus</i> sp.</td><td>China</td></tr>
<tr><td>2004(1)</td><td><i>Ligustrum</i> sp.</td><td>China</td></tr>
<tr><td>2006(1)</td><td><i>Brachychiton</i> sp.</td><td>Israel (2)</td></tr>
<tr><td>2006(1) + 2008</td><td><i>Rosa</i> sp.</td><td>South Africa, China (3)</td></tr>
</table>
(1) The final diagnosis was only possible in 2007 using molecular tests for confirmation.</td></tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>(2) Information needed on the exact origin of the consignment as the NPPO of Israel declares that the pest is not known to occur in Israel.
(3) It has also been detected in Germany on plants of <i>Rosa</i> spp. imported from China.
Finally, the association of the pest with the plants will be the same all year through.</td>
</tr>
<tr>
<td>1.5 How likely is the concentration of the pest on the pathway at origin to be high, taking into account factors like cultivation practices, treatment of consignments?</td>
<td>likely
low</td>
<td>Little information is available about cultivation practices in Africa and Asia against nematodes. However, recent findings of <i>M. enterolobii</i> in imported ornamentals in the Netherlands show that the concentration of the pest on the pathway at origin can be high: imported <i>Rosa</i> sp. and <i>Brachychiton bidwillii</i> were heavily infested. In a root sample of <i>Brachychiton bidwillii</i>, 12,360 eggs, 4,380 juveniles and 200 females were found (source: NPPO of the Netherlands).
It should be noted that infestation levels may depend on the type of plants (seedlings are less likely to have as high infestation levels as perennial older plants) and on the types of soil (see question 1.20).</td>
</tr>
<tr>
<td>1.6 How large is the volume of the movement along the pathway?</td>
<td>massive
low</td>
<td>Many rooted plants are imported from China, Brazil, South Africa and the United States (see also question 1.2).
Estimation of numbers of imported rooted plants in the EPPO region is not possible as no detailed data is available neither is it possible to distinguish between plants with soil attached or bare-rooted.
Statistical data on volumes of trade (in 100 kg) have been retrieved from EUROSTAT for the 27 EU countries and are as follows:

Table 2. Volumes of import of plants for planting (except bulbs and rhizomes) in 100 kg into the EU including details from countries where <i>M. enterolobii</i> is known to occur
<table>
<tr><th>Country of origin</th><th>2006</th><th>2007</th><th>2008</th></tr>
<tr><td>ALL COUNTRIES</td><td>1050536</td><td>1148566</td><td>1084066</td></tr>
<tr><td>TOTAL COUNTRIES WHERE PEST PRESENT</td><td>304564</td><td>344241</td><td>329811</td></tr>
<tr><td>CHINA</td><td>184391</td><td>208398</td><td>195186</td></tr>
<tr><td>GUATEMALA</td><td>86574</td><td>101591</td><td>104214</td></tr>
<tr><td>UNITED STATES</td><td>13543</td><td>17111</td><td>17780</td></tr>
<tr><td>BRAZIL</td><td>6228</td><td>7117</td><td>4919</td></tr>
<tr><td>IVORY COAST</td><td>2117</td><td>2067</td><td>2805</td></tr>
<tr><td>CUBA</td><td>8546</td><td>5796</td><td>2510</td></tr>
<tr><td>SOUTH AFRICA</td><td>2159</td><td>2097</td><td>2140</td></tr>
<tr><td>VIETNAM</td><td>1006</td><td>56</td><td>169</td></tr>
<tr><td>SENEGAL</td><td>1</td><td>8</td><td>87</td></tr>
<tr><td>VENEZUELA</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>BURKINA FASO</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>MALAWI</td><td>0</td><td>0</td><td>0</td></tr>
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<td></td>
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<table>
<tr><td>TRINIDAD AND TOBAGO</td><td>0</td><td>0</td><td>0</td></tr>
</table>
(The units used in EUROSTATS are difficult to interpret as weight for a unit of the same species may vary a lot between a seedling and a grown plant with growing media attached but they give a tendency).
No detailed information is readily available for other EPPO countries but most of the trade of plants for planting destined to other EPPO countries is usually imported through EU countries.

About 25 million rose plants were imported from China into the Netherlands from 2005 until 2007 (source: NPPO of the Netherlands). In Germany, a total of 1.6 million *Rosa* plants from China were imported in February and March 2008 in North Rhine Westphalia (NPPO, 2008). (One consignment of 500 000 plants was found infested with *M. enterolobii).*

The imports from countries where the pest is present equal to 1/3 of the total trade in plants for planting from third countries. The EWG considered that it was massive.
</td>
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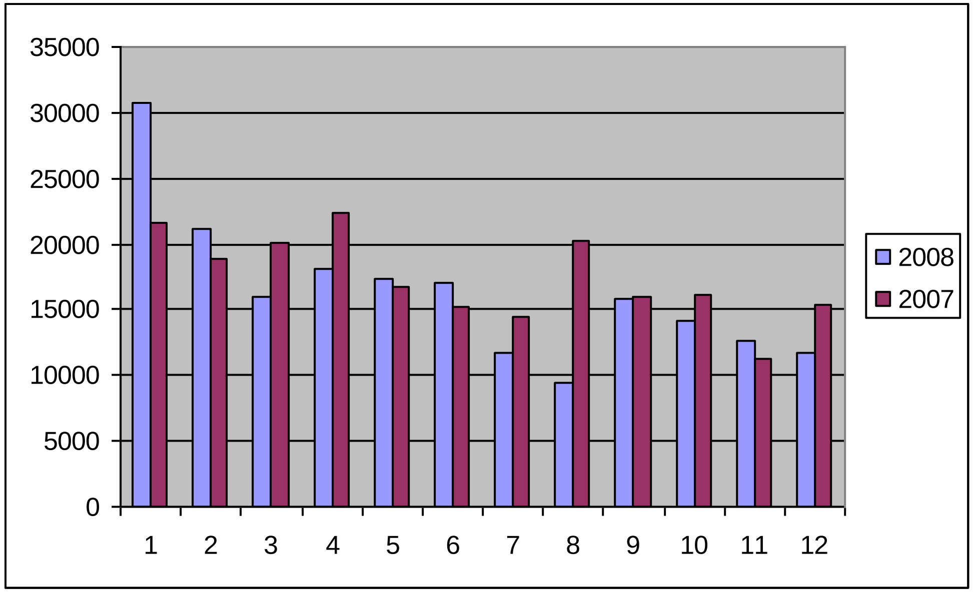
<tr>
<td>**1.7** How frequent is the movement along the pathway?</td>
<td>very often
low</td>
<td>Import of rooted plants occurs year-round.

The following graph shows the repartition of volume of imports of plants for planting (except seeds, bulbs, rhizomes) from China into the countries of the European Union in 2008 (in 100 kg) (data retrieved from EUROSTAT). Although variations are noted between the months, imports occur all year round.</td>
</tr>
</table>

		
1.8 How likely is the pest to survive during transport /storage?	very likely low (see comment)	There is no reason to assume that *M. enterolobii* is not able to survive in transit. For example, in growing media, such as sand, the nematode could survive as egg masses. Recent studies with the Swiss *M. enterolobii* populations revealed that the nematode could survive for up to 13 month in soil at 3°C in the absence of a host plant. The number of surviving nematodes was not correlated to the initial density of *M. enterolobii* (Kiewnick unpublished 2009). The findings/interceptions of live *M. enterolobii* on imported ornamentals also show that this nematode species can survive transport. Other *Meloidogyne* spp. such as *M. chitwoodi* are able to survive transit on all suitable pathways (Tiilikkala *et al.*, 1995).
1.9 How likely is the pest to multiply/increase in prevalence during transport /storage?	unlikely low	Depending on the temperature during transport, the nematode may be able to complete its life cycle, however, transport time will generally be too short to allow for multiplication, e.g. transport time from China is about one month while *M. enterolobii* has a 6 weeks generation time at about 20ºC (Karssen & Moens, 2006; see also question 1.28). However, development will go on and eggs for example may hatch during transport unless plants are transported/stored under cool conditions which do not allow for development of the species. In non-host plants the nematode will not multiply.
1.10 How likely is the pest to survive or remain undetected during existing management procedures (including phytosanitary measures)?	likely low/	This depends on the infestation rate. If plants are slightly infested or in the early stage of infection, symptoms are not readily seen. Often, young plant material does not show clear symptoms and initial *Meloidogyne* infections are easily overlooked. Nevertheless it is quite likely that a moderate to heavy '*Meloidogyne* – infestation' will be recognized during an inspection or test (on tomato or cucumber large gall will develop) but symptoms caused by *M. enterolobii* might be confused with the symptoms caused by other *Meloidogyne* species. Detection in soil attached to plants is not possible by visual inspection.

		In a worst case scenario (plants recently infected) the pest is likely to remain undetected during existing management procedures?
1.11 How widely is the commodity to be distributed throughout the PRA area?	very widely low	Ornamental plants and cuttings are distributed throughout the EPPO region.
1.12 Do consignments arrive at a suitable time of year for pest establishment?	yes low	Time of importation is not important for this pest.
1.13 How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?	Plants to be planted in soil very likely Low uncertainty Pot plants Likely	The following situations may occur: In case plants will be planted directly in the soil in areas/glasshouses with suitable conditions the soil will become infested (transfer is **very likely)** In case pot plants are kept in greenhouses for several weeks or months before being sold to end-consumers the greenhouse may become infested and nematodes may be spread through the irrigation system and management practices to other potted plants. Nevertheless the pest has entered Dutch pot plant glasshouses many times as shown by the findings but has, as far as is known, not lead to problems/establishment in glasshouses (transfer is **moderately likely**). Plants that are only grown in pots may also lead to infestation of soil in the importing country. Pot plant nurseries could remove potting soil from imported plants and replace it with new potting soil. The soil that has been removed might be added to greenhouse soil at other nurseries. No specific data on such practice was available to the EWG and this may be considered as an hypothetical scenario. (If this happens transfer is **moderately likely)** The EWG considered that the main transfer pathway is via ornamental plants (see also question 1.1). It recognized that there is no straightforward explanation on how the transfer from ornamental plants to vegetable production can happen and could only make some hypotheses: Soil from pot plants is reused for other production. Producers of vegetables may rent their glasshouses to other producers growing ornamental plants during certain periods of the year. Note the EWG also formulated the hypothesis that producers in green houses may have a "hobby corner" where they grow other plants and that this may be a source of infestation. Core members commented that this is not a good production practice that is not frequent.
1.14 How likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) to aid transfer to a suitable host or habitat?	likely medium	When imported infested plants are subsequently grown in a (greenhouse or field) nursery, this will aid transfer to a suitable host. If plants are for final consumers as indoor pot plants the risk of transfer to suitable hosts is low although people may dispose the soil in their gardens when they dump their plants.
1.15c The overall probability of entry should be described and risks presented by different		**Probability of entry is considered high taking into account the likelihood of association and concentration of the pest at origin with the pathway, the volumes of trade and frequency, the likelihood to survive and to remain undetected. Almost all component of entry potential have**

pathways should be identified		**been rated high.** **If imported infested plants are subsequently grown in a (greenhouse or field) nursery, this will aid transfer to a suitable host. If plants are for final consumers as pot plants the risk of transfer to suitable hosts is lower.**

Stage 2: Pest Risk Assessment - Section B : Probability of establishment

<table>
<tr>
<td>**1.16** Estimate the number of host plant species or suitable habitats in the PRA area.</td>
<td>Many
low</td>
<td>The pest is polyphagous and has many host plants including cultivated plants and weeds in different families as confirmed in particular by the extensive testing of hosts conducted in Switzerland (Kiewnick *et al*., 2008). Some host plants are not cultivated but they are also present in the region (e.g. *Acacia* spp.). Many hosts are present in the EPPO region (see question 6). It attacks trees as well as herbaceous plants.
It is expected that *M. enterolobii* will attack more crop plants in the EPPO region than are presently known to be host plants because host plant research has so far been carried out in (sub) tropical countries only (see question 6). Many host plants are still to be identified. In this case the rating for this question is likely to become “very many host plants” uncertainty in such case will only result in an increase of the rating.</td>
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<tr>
<td>**1.17** How widespread are the host plants or suitable habitats in the PRA area? (specify)</td>
<td>very widely
low</td>
<td>Not all known host plants are present in the EPPO region, but those that are present are widespread, such as rose, cucumber, tomato, pepper, egg plants, potato, broccoli and bean. An illustration of the area occupied by tomato and cucumber and their relative importance is presented in Table 3.

Table 3. Vegetable production data from FAO datasets for vegetable production. The figures are derived from mean production values over the years 2004 – 2006 (raw data and calculations at Appendix 3).
<table>
<tr><td></td><td>Tomato</td><td>Cucumber</td></tr>
<tr><td>Total production in the PRA area (ha)</td><td>1 123 826</td><td>345 767</td></tr>
<tr><td>Proportion of total vegetable production area</td><td>16.0 %</td><td>4.9 %</td></tr>
</table>
</td>
</tr>
<tr>
<td>**1.19** How similar are the climatic conditions that would affect pest establishment, in the PRA area and in the current area of distribution?</td>
<td>Largely similar
Low</td>
<td>*Meloidogyne enterolobii* has so far been detected outdoors or under protected cultivation in the following tropical and subtropical regions:

Africa: Senegal, Ivory Coast, Burkina Faso, Malawi, Togo, South Africa
South America: Brazil (Bahia, Maranhao, Pernambuco, Rio de Janeiro, Sao Paulo, Minais Gerais, Piaui, Ceara, Parana, Rio Grande do Norte, Rio Grande do Sul), Venezuela,
Central America: Guatemala
Caribbean: (Cuba, Puerto Rico, Guadeloupe, Martinique, Trinidad and Tobago)
North America: USA/Florida
Asia: China/Hainan Island, Vietnam.

In Europe, *Meloidogyne enterolobii* has so far been detected only under protected cultivation Switzerland (2 greenhouses), France/Brittany (plastic tunnel).

Based on the present knowledge of distribution of *M. enterolobii*, this species needs a relatively high temperature to develop. These conditions are present outside in the southern part of the EPPO region and in greenhouses in the entire EPPO region. The precise temperature requirements of *M. enterolobii*</td>
</tr>
</table>

		have not been studied. It is assumed that this species has similar climatic condition requirements as other tropical root knot nematode species. The following tropical root knot nematode species are known to occur in the EPPO region: *M. javanica*, *M. incognita* and *M. arenaria* (CABI, 2002a, 2002b; CABI 2003) and have been recorded many times outdoors in the southern part of the region. In the northern parts of the EPPO region, tropical root-knot nematode species have been detected under protected cultivation. A recent study has shown that *M. incognita* is able to survive outdoors (overwinter) in the Northwest of Germany (pers. comm., J. Hallmann, 2009). *M enterolobii* has been found together with *M. hapla* (a northern root knot nematode) in Switzerland (Kiewnick, pers. comm. 2009). This indicates that *M. enterolobii* has similar temperature requirements than *M. hapla*. Tropical root knot nematodes are not limited by dry conditions. They develop more quickly in irrigated soils but irrigation is not a limiting factor for establishment Meloidogyne sp. have a mechanism for survival (Evans & Perry, 2009). Based on these facts, it can be assumed that suitable climatic conditions can be found in all parts of the EPPO region.
1.20 How similar are other abiotic factors that would affect pest establishment, in the PRA area and in the current area of distribution?	largely similar low	According to Braasch *et al*. (1996), *Meloidogyne* spp. can occur on a wide range of soil types, but their association with crop damage is more readily observed in sandy soils (because of the limitation of nutrients and water). In Switzerland the nematode occurs on soil with high organic material. In Florida *M. enterolobii* has been found in the field in sandy flatwood soil[1] (personal communication: Janete Brito, 2009). Generally the water table is beneath this layer, rising and falling with heavy rainfall and drought conditions. Both observations indicate that areas with coarse-textured (sandy) soils in the EPPO region are the highest-risk areas for *M. enterolobii*. Such sandy soils are present in the EPPO region (see map in Appendix 4). As with many other nematode species, root-knot nematodes do not persist readily in fine-textured clay mineral soils (Potter & Olthof, 1993).
1.21 If protected cultivation is important in the PRA area, how often has the pest been recorded on crops in protected cultivation elsewhere?	occasionally low	*M. enterolobii* was recorded on tomatoes under plastic tunnel in France (Anthoine pers. comm., 2009). *M. enterolobii* is present in two greenhouses producing vegetables in Switzerland probably since at least 2004, but at that time the *Meloidogyne* sp. could not be determined. In one of these greenhouses, tomato is grown organically. In the other one, tomato is grown in a conventional way It is also recorded under protected conditions in Florida (Brito pers. comm., 2009).
1.22 How likely is it that establishment will occur despite competition from existing species in the PRA area?	very likely low	Co-existence of two or more *Meloidogyne* species on the same host in the field is well known, and suggests strongly that competition between these nematode species is not an issue (Karssen, 2002). In Florida the pest has been found in association with either *M. arenaria, M. floridensis, M. incognita,* or *M. javanica* (Brito *et al*., 2008). In Switzerland it is found in association with *M. hapla (*Kiewnick pers. comm., 2009). In a rose consignment from China it was identified together with *M. hapla*

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[1] A typical flatwood soil profile consists of a 6-inch surface layer of friable gray fine sand (ca. 92 to 96% sand), a 50 cm subsurface layer of light gray fine sand, a 15 cm subsoil of dark reddish brown fine sand organic stained layer, with a brown and yellowish brown fine sand substratum.

		(Karssen pers. comm., 2009). In a recent study, the Swiss *M. enterolobii* population was able coexist with *M. arenaria* on tomato (Kiewnick pers. comm. 2009). No information on competition from other species (more distantly related nematode genera) is available at present.
1.23 How likely is it that establishment will occur despite natural enemies already present in the PRA area?	very likely low	In general, *Meloidogyne* spp. have many natural enemies or antagonists (Kok, 2004). However, natural enemies like fungi and *Pasteuria penetrans* have a relatively low impact on tropical *Meloidogyne* species in the temperate climate zones (Karssen & Moens, 2006). In Florida three isolates of *Pasteuria penetrans* were not able to infect *M. enterolobii* (Brito *et al.*, 2004a). Similar results were obtained in Brazil (Carneiro *et al.*, 2004). Isolates of *Pasteuria penetrans* from different continents could attach to juveniles of *M. enterolobii* but the biocontrol effect is not known (Trudgill *et al.*, 2000). Information on natural enemies of *Meloidogyne* spp. other than *P. penetrans* is scarce but see question 2.11.
1.24 To what extent is the managed environment in the PRA area favourable for establishment?	highly favourable low	Cultivation practices do not have a major impact on the establishment of *Meloidogyne* species. The establishment of Meloidogyne spp. can be mitigated only with the incorporation of resistant or non host plants into the crop rotation. This is virtually impossible for *M. enterolobii*. Other *Meloidogyne* spp., like *M. incognita*, have established in large parts of the EPPO region (CABI, 2002 a), in greenhouses and in the open field. Due to the similarity with these species, *M. enterolobii* would be able to establish in the same way
1.25 How likely is it that existing pest management practice will fail to prevent establishment of the pest?	likely low	In general, control measures against nematodes, such as crop rotation, green-manure cover crops and nematicides reduce population levels but are not likely to prevent establishment. Effective crop rotation schemes may be difficult to implement since *M. enterolobii* has a wide host range (see Q 6). In addition varieties resistant to *M. enterolobii* are not currently available.
1.26 Based on its biological characteristics, how likely is it that the pest could survive eradication programmes in the PRA area?	Very likely outdoors Moderatley likely indoors	*M. enterolobii* can survive in root debris and can be found in different soil layers. This makes it very likely to survive eradication programmes. The pest has a large host range and extended black fallow period may be needed to achieve eradication. There is not data on a minimum period that would be necessary to achieve eradication. Nevertheless there is no example of successful eradication of root knot nematodes under field conditions. Steaming or fumigation of the soil will usually not lead to complete eradication of the pest as the treatment will not penetrate sufficiently deep. Eradication is likely to be similarly difficult in glasshouses with production in natural soil. In a site with hydroponic production or where the entire substrate can be treated eradication is feasible. A successful eradication of *M. hapla* is reported from the Netherlands in hydroponic production, this involved elimination of the plants and cleaning of the irrigation system (Karssen pers. comm., 2009). Very likely outdoors

		Moderately likely indoors
1.27 How likely is the reproductive strategy of the pest and the duration of its life cycle to aid establishment?	very likely low	*M. enterolobii* reproduces by mitotic parthenogenesis and is a polyploid organism (2n=44-46). Therefore, one second-stage juvenile can start a new population as it reproduces without sex (Yang & Eisenback, 1983). Within a greenhouse, it completes one generation every 6 weeks. Under field conditions in southern Europe, the maximum number of generations is estimated (at 20ºC with a 6 week generation time) at about 4-6 per year (Karssen & Moens, 2006). This is confirmed by observation in the Swiss outbreaks (Kiewnick *et al.*, 2009).
1.28 How likely are relatively small populations to become established?	very likely low	One second-stage juvenile can start a new population. *M. enterolobii* females are able to lay 100 – 800 eggs (Karssen, pers. comm., 2009). Combined with the most likely absence of specific natural enemies and the fact that *M. enterolobii* is able to reproduce on many plant species (see Q 6), it is likely that small populations of *M. enterolobii* can establish in a new area.
1.29 How adaptable is the pest? Adaptability is:	moderate medium	There is little information available to make a judgment on this question. However, the fact that the species has a very wide host range and that it is virulent to most known *Meloidogyne* resistance genes (Fargette, 1987; Cetintas *et al.*, 2008; Brito *et al.*, 2007b; Brito *et al.*, 2007a; Carneiro *et al.*, 2006; Berthou *et al.*, 2003) may give an indication that the pest is adaptable. In addition the fact that the pest is found in different climatic zones is an indication of adaptability.
1.30 How often has the pest been introduced into new areas outside its original area of distribution?	Often high	The origin of the pest is not known. Phylogenetic studies are needed to clarify the relationships between the different populations around the world. It has been reported from the following countries/ regions: - China (1983) on Pacara ear pod trees (Yang & Eisenback, 1983), these trees where introduced from South-Africa (Karssen pers. comm. 2009). - Caribbean basin (1988) on eggplants (Rammah & Hirschmann, 1988). - South-America: Brazil (2001 and 2006) on guava; and on resistant pepper and tomato (Carneiro *et al.*, 2001; 2006). - USA, Florida (2001): several ornamental nurseries infected (Brito *et al.*, 2004a). - France (Blok *et al.*, 2002): one tomato crop under plastic tunnel (Anthoine pers.comm., 2009). -Switzerland (2004): two tomato greenhouses (see Q 1.22) (Kiewnick *et al.*, 2008). - Vietnam (2008) on guava (Iwahori *et al.*, 2009) As the origin of the pest is not known it is difficult to identify the instances where the pest has been introduced.
1.31a Do you consider that the establishment of the pest is very unlikely ?	no	Establishment is not very unlikely. It is likely outdoors in the southern part of the region and in protected conditions throughout the region.
1.31c The overall probability of establishment should be described.		**The probability of establishment is considered high. The pest has a wide host range and has established in two locations in the EPPO region. In addition, similar tropical root knot nematodes have established in the EPPO region. The EWG considered that the probability of**

		establishment outside protected cultivation in the Northern part of the region is low to medium because of temperature requirements of the tropical root knot nematodes.

Stage 2: Pest Risk Assessment - Section B : Probability of spread

1.32 How likely is the pest to spread rapidly in the PRA area by natural means?	very unlikely low	The capacity of *M. enterolobii* for natural movement is very low and comparable to other *Meloidogyne* species; according to Tiilikkala *et al.* (1995), free-living second-stage juveniles can move 1-2 m at maximum per year.
1.33 How likely is the pest to spread rapidly in the PRA area by human assistance?	likely low	*M. enterolobii* can easily be spread throughout the EPPO region with infested rooted plants or soil. It can also be spread by machinery visiting different fields. Irrigation system may also enable the spread of the pest. The pest has been recorded in vegetable production in France and Switzerland and there is no indication that it has spread from the infested places of production. Nevertheless if the pest establishes in nursery production the likelihood of spread by human assistance is likely.
1.34 Based on biological characteristics, how likely is it that the pest will not be contained within the PRA area?	unlikely low	In agricultural areas, spread can be contained in fields by taking appropriate hygienic measures (cleaning machinery, etc) and prohibit the transportation of soil and infested plants. Such measures are not always easy to implement in practice. However, total prevention of spread of latent infestations will be almost impossible with the techniques available. The intensity of soil sampling in suspected areas will determine the success ratio, but a 100% watertight system is not feasible.
1.34c The overall probability of spread should be described.		**Probability of spread is high (natural spread is low but human spread is high)**

Stage 2: Pest Risk Assessment - Section B : Conclusion of introduction and spread and identification of endangered areas

1.35a Conclusion on the probability of introduction and spread. (Your conclusions from the previous modules will appear in the box below.)		**Probability of entry is considered high taking into account the likelihood of association with the pathway and concentration of the pest at origin, the volumes of trade and frequency, the likelihood to survive and to remain undetected. Almost all components of entry potential have been rated high.** **If imported infested plants are subsequently grown in a greenhouse or a field, this will aid transfer to a suitable host. If plants are for final consumers as pot plants the risk of transfer to suitable hosts is lower.** **The probability of establishment is considered high. The pest has a wide host range and has established in two locations in the EPPO region. In addition, similar tropical root-knot nematodes have established in the EPPO region. The EWG considered that the probability of establishment outside protected cultivation in the Northern part of the region is low to medium because of temperature requirements of the species.** **Probability of spread is high (natural spread is low but human spread is high).**
1.35b Based on the answers to questions 1.16 to 1.34 identify the part of the PRA area where		**As the pest can be present under protected conditions the whole EPPO region is considered to be the endangered area, the Mediterranean part is considered as being most at risk as the pest**

presence of host plants or suitable habitats and ecological factors favour the establishment and spread of the pest to define the endangered area.		**is more likely to establish outdoors than in the northern part of the region.**

Stage 2: Pest Risk Assessment - Section B: Assessment of potential economic consequences

In the economic impact the EWG focussed on tomato and cucumber productions as these are major hosts for M. enterolobii in the region for which some information is available.

<table>
<tr>
<td>2.1 How great a negative effect does the pest have on crop yield and/or quality to cultivated plants or on control costs within its current area of distribution?</td>
<td>major
low</td>
<td>
<p>All available literature refers to <i>M. enterolobii</i> as a highly virulent and damaging nematode species, when compared to the other tropical root-knot nematodes. Brito <i>et al</i>. (2004b) state that <i>M. enterolobii</i> is highly virulent to many vegetables.</p>
<p>Only few detailed studies have been made so far on yield losses. In tomato trials the strongest reduction in fruit yield was caused by <i>M. enterolobii</i> compared to other tropical root-knot nematodes i.e. the yield was 0.9 kg in a microplot infested with <i>M enterolobii</i> compared to 2.6 kg in the control, i.e. 65% reduction (Cetintas <i>et al</i>., 2007).
In fact this nematode produces bigger galls (which can be correlated with reduction of crop yields). Results for the other nematodes is shown in the table below (based on Cetintas <i>et al</i>., 2007)</p>
<table>
<tr><th></th><th>Fruit yield</th><th>% of losses</th></tr>
<tr><td><i>M. arenaria</i></td><td>1.5</td><td>42 %</td></tr>
<tr><td><i>M. floridensis</i></td><td>1.5</td><td>42 %</td></tr>
<tr><td><i>M. incognita</i></td><td>1.4</td><td>46 %</td></tr>
<tr><td><i>M. javanica</i></td><td>1.4</td><td>46 %</td></tr>
<tr><td><i>M. enterolobii</i></td><td>0.9</td><td>65 %</td></tr>
<tr><td>Control plot</td><td>2.6</td><td></td></tr>
</table>
<p>In two greenhouses in Switzerland yield losses of up to 50% and severe stunting of tomato rootstocks, resistant to <i>M. incognita</i>, <i>M. javanica</i> and <i>M. arenaria</i>, and cucumber were observed (Kiewnick <i>et al</i>., 2008).</p>
<p>Besides the above-mentioned damage, <i>M. enterolobii</i> is of particular concern because it can reproduce on cultivars with the <i>Mi-1</i> resistance gene (Fargette, 1987; Cetintas <i>et al</i>., 2008; Brito <i>et al</i>., 2007b; Brito <i>et al</i>., 2007a; Carneiro <i>et al</i>., 2006; Berthou <i>et al</i>., 2003). The <i>Mi</i> resistance gene confers resistance to the three major tropical-subtropical nematode species, such as <i>M. incognita</i>, <i>M. javanica</i> and <i>M. arenaria</i> (Zoon <i>et al</i>., 2004). <i>M. enterolobii</i> was reported in São Paulo State, Brazil, parasitizing both root-knot nematode resistant pepper, rootstock ‘Silver’ and resistant tomato plants (cv. ‘Andrea’ and ‘Débora’). Infested plants are chlorotic, and had a reduction in plant growth, and a consequent decline in yield quality and quantity. Severely infested root systems were poorly developed, distorted by multiple galls and devoid of fine roots (Carneiro <i>et al</i>., 2006). Furthermore,</p>
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		Kiewnick *et al.* (2009) demonstrated that the two Swiss *M. enterolobii* populations were more virulent and pathogenic on tomato compared to *M. arenaria*. In Cuba, *M. enterolobii* is more damaging in coffee than *M. incognita, M. arenaria* and *M. javanica* and is considered one of the most important pests of the coffee crop (Rodriguez *et al*., 1995b; Rodriguez *et al*., 2001). In South Africa, *M. enterolobii* was observed to cause severe root-knot symptoms in guava plantings at Nelspruit (Willers, 1997a). Without treatment, all infected guava trees were either dead or in the final stages of decline. *M. enterolobii* was reported as the causal agent of severe crop losses in guava in the municipalities of Petrolina (Perambuco state), and Curaça and Manitoba (Bahia), all located in the semi-arid zone of the north-eastern region of Brazil (Carneiro *et al.*, 2001) and approximately 70% of the guava plants cultivated in the Medium Sao Francisco, Brazil have died due to the infection of *M. enterolobii* (Cid & Carneiro, 2007). In Guadeloupe and Martinique, *M. enterolobii* causes complete dieback, killing young trees of guava from 5 to 7 years after planting. (IRD, 2006).
2.2 How great a negative effect is the pest likely to have on crop yield and/or quality in the PRA area without any control measures?	major medium	*M. enterolobii* is highly virulent and produces more root galls compared to other root-knot nematodes (Cetintas *et al.*, 2007; Fargette, 1987). 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*, *M. javanica* and *M. arenaria* which are well established in large parts of the PRA-area (CABI, 2007). For example, the potential effect of *M. incognita* on field crop yield is large (usually about 20% but crop losses up to 100% have been noted) as shown by various experiments (e.g. CABI, 2007; Russo *et al*., 2007). In southern parts of the EPPO region, where the outdoor climate is suitable for development and survival of *M. enterolobii*, damage levels as a result of *M. enterolobii* infestations in field crops may be similar to those noted in the pest's current area of distribution (see question 2.1). It should also be noted that the *Mi*-1 resistance gene, which has been introduced in many cultivated tomato varieties (Zoon *et al*., 2004), would be of no use against *M. enterolobii* infestations. It should be noted that at higher soil temperatures the resistance conferred by *Mi-1*gene is also not effective against root-knot nematodes. Considering the broad host range including economically important crops like tomato, sweet pepper, and eggplant, and the impact of *Meloidogyne* infestations in general, the economic impact of establishment of *M. enterolobii* is assessed to be large for the entire EPPO region. Even if no detail is available an infestation of grapes with *M. enterolobii* has been detected in the Netherlands (see Appendix 1), showing that grape is a host plant. It is, however, unknown how much damage *M. enterolobii* can cause on grapes. If it can cause significant growth reduction and yield losses in grapes, its potential economic effect is very high for wine producing areas in the EPPO region. Control measures are not available once a vineyard has been infested because grape plants are usually grown for decades before being replanted. Grapes with resistance against *M. incognita* are

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<p>known but not against M. enterolobii (Karssen pers. comm. 2009).</p>
<p>An analysis of annual losses that may result from the presence of the pest was carried out (Table 4) based on the information on crop losses in the areas where the pest is present, the quantity harvested in EPPO countries and average crop prices per country (information obtained from FAO stats) (see Appendix 3). The scenario envisaged is that 50 % of the production is affected (this is hypothetical and not based on any expected spread mechanism). In order to perform a study for a given coming period (e.g. next 10 or 20 years) information would be needed on how much of the area is expected to become infested after the introduction but such information is not available. The calculations assume crop losses of 5 % and 30 % (although losses of up to 50 % have been reported for protected tomato see above). This allowed an estimation of the yield losses over 5 years to be made.</p>
<p>Table 4. Summary of estimated potential annual crop losses due to root knot nematodes. These data were derived by extracting information from FAO-Stat on producer price and production quantity. The figures are derived from mean production values over the years 2004 – 2006 (raw data and calculations at Appendix 3) and an hypothesis that 50 % of these productions would be affected.</p>
<table>
<tr><th></th><th>Tomato</th><th>Cucumber</th></tr>
<tr><td>Total EPPO zone production (millions of tonnes)</td><td>37.8</td><td>8.0</td></tr>
<tr><td>Total EPPO zone production (millions of Euros)</td><td>12210.3</td><td>3372.9</td></tr>
<tr><td>5 % crop yield losses (millions of Euros) in 1 year</td><td>305</td><td>84</td></tr>
<tr><td>30 % crop yield losses (millions of Euros) in 1 year</td><td>1832</td><td>506</td></tr>
</table>
<p>A detailed study of the potential economic impact for the Netherlands has been performed and is included in the Dutch PRA for M. enterolobii.</p>
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<tr>
<td>2.3 How easily can the pest be controlled in the PRA area without phytosanitary measures?</td>
<td>with much difficulty
low</td>
<td>
<p>In general plant-parasitic nematodes are very difficult to control.
Recommended good plant protection practices for the EPPO region regarding Meloidogyne species are included in the Standard in the series PM 2 (PM 2/13, PM 2/29, PM 2/30, PM 2/32) and are as follows:</p>
<p>For protected cultivation it is recommended to use planting material free from nematodes and apply good general hygiene to prevent Meloidogyne spp. infestations. Cultural practices such as crop rotation and cultivation are also recommended. In case of infestation hot water treatment of plant material, and steam sterilization and solarization of the soil are recommended. Weeds should be thoroughly controlled. Use of root-knot nematode resistant cultivars where available is also recommended.</p>
</td>
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</table>

For outdoor crops, similar recommendations are made with the addition of nematicide chemical treatment but this is not recommended except for breeding material.

These are recommendations for good plant protection practices and are not representative of all production practices.

In the EPPO region the following measures are applied in order to control *Meloidogyne* species:

Resistant cultivars

The use of root-knot resistant cultivars is not an option to control *M. enterolobii* as this nematode is able to multiply on current resistant cultivars (see question 2.1). For all producers depending on resistant cultivars in particular organic farmers, the control of this nematode will be very difficult.
As stated before, the Mi-resistance gene has been introduced in many tomato varieties. Information has been gathered from France and Spain.
In France 90 % of tomato plants are grafted and most rootstock have the Mi-resistance gene (Wuster, pers.comm., 2009). In Spain, on average 30% of the varieties have the Mi-resistance gene. Nevertheless there is a huge variation in the use of resistant varieties between the different producing areas in the country (Almeria and Murcia use 30% of resistant whereas in comunidad Valenciana region the proportion can reach 100%) (Hoyos Echevarria, 2007; Guitian Castrillon pers.comm. 2009)

Fumigation

Soil fumigation with methyl bromide is effective but the use of methyl bromide will be phased out due to its negative impact on the ozone layer (Montreal protocol (e.g. http://www.ciesin.org/TG/PI/POLICY/montpro.html). The alternative fumigants metam sodium and cis-dichlorpropene reduce the nematode population in soil by 60 to 90% (Anonymous, 1987). Cis-dichlorpropene was excluded from the harmonized EU list of active substances but it is again under review in the EU. It is yet unsure if metam sodium will be registered in Europe (http://ec.europa.eu/food/plant/protection/evaluation/index_en.htm; website visited 10/09/2008).

Non-fumigant nematicides

Ethoprophos, fosthiazate and oxamyl are relatively easy to apply. They are, however, less effective than the fumigants since they do not kill nematodes but interfere with their mobility. Therefore, these pesticides are only effective during the first part of the growing season. There is no information available on the efficacy of these nematicides against *M. enterolobii*.
In Tunisia cadusafos is used (Raouani, pers.comm. 2009) but is not available for the EU countries.

		Crop rotation/ fallow Fallow is a very effective method against *Meloidogyne* spp. (Scholte, 2000; Noling, 2005). Weed control will be needed during fallow since *M. enterolobii* may multiply on several weed species. Crop rotation is in general a good control method for (root-knot) nematodes. Amongst the (experimental) non-host plant species of *M. enterolobii* are thyme (*Thymus vulgaris*), garlic (*Allium sativum*) (Rodriguez *et al*., 2003), maize (*Zea mays*) (Guimarez *et al*., 2003). Options that are not widely used or where further development is needed Solarisation (not applicable in the entire EPPO region) Solarisation may be used in tropical and sub-tropical regions. According to Noling (2005), lethal temperatures can be achieved up to a depth of 20 cm, but nematodes present in deeper soil layers will not be killed. In North Western Europe, temperatures are too low for solarisation. Information was requested from North African countries. Information was received from Tunisia indicating that solarization is used in particular in South Tunisia (Raouani, pers.comm., 2009) Biofumigation [2](the technique needs further development) Steam sterilization Steam sterilization is effective but is expensive. In greenhouses, nematodes can be controlled by steam sterilization in crops grown in soil. However, also for high value crops steam sterilization is an expensive method especially due to increased energy prices in recent years. Soil flooding Soil flooding is effective but not an option for many soils for different reasons (e.g. soil permeability does not allow for flooding, prohibition of the use of surface water by law etc.). Biological control Biological control may be part of an integrated approach to control nematodes but is on it self not very effective (Noling, 2005). At present, no biological control product is commercially available that is known to be highly effective against root knot nematodes. For container grown plants and plants grown on artificial substrates like rock wool, perlite and pumice, hygienic measures should avoid nematode infestation. Once, plants and substrate have been infested control is very difficult apart from hydroponic production or when the entire substrate can be treated. (see 1.26).

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[2] Biofumigation refers to the suppression of soil-borne pests and pathogens by biocidal compounds, principally isothiocyanates (ITCs) released when glucosinolates (GSLs) in the tissues of Brassica plants are hydrolysed in soil.

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<tr><td></td><td></td><td></td></tr>
<tr><td>2.4 How great an increase in production costs (including control costs) is likely to be caused by the pest in the PRA area?</td><td>moderate
low</td><td>In production places where resistant cultivars are used to control other root-knot nematodes, or in places of production where no root-knot nematodes occur and no chemical treatment is carried out, the increase in production costs is likely to be major.
When chemical treatments are already applied to control other root-knot nematode species, increase in production costs is likely to be minimal.

Production costs will increase due to increased crop protection costs. In greenhouses in northern Europe, growers will have to increase the frequency of steam sterilization and/or the use of nematicides. Vermeulen <i>et al.</i> (2008) estimate the present annual costs for control of <i>Meloidogyne</i> spp in soil-grown crops in Dutch greenhouses between about 2 and 3 million euro (Table 5). These costs are mainly due to steam sterilization and to a lesser extent due to the use of nematicides. Costs for steam sterilization are highly dependent on the price of gas. Vermeulen <i>et al.</i> (2008) used a gas price of € 0.30 per cubic meter in their studies.
A crop free period may be necessary to decrease populations of <i>M. enterolobii</i> since the nematode can affect many crop plant species. Growers may conduct soil fumigation or steam sterilization of the soil. Both methods are relatively expensive and especially steam/heat sterilization will be too expensive for most outdoor crops. The control methods are not 100% effective and will have to be repeated after some years.
Possibilities for crop rotation need to be investigated.

Table 5. Estimates of annual control costs of <i>Meloidogyne</i> spp. in greenhouses in the Netherlands (Vermeulen <i>et al</i>., 2008).
<table>
<tr><th>Crop</th><th>Growing medium</th><th>Total area in 2007 (ha)</th><th>Annual control costs (in thousands of €)</th></tr>
<tr><td>Chrysanthemum</td><td>Soil</td><td>485</td><td>330 – 550</td></tr>
<tr><td>Organically grown cucumber</td><td>Soil</td><td>11</td><td>223</td></tr>
<tr><td>Organically grown tomato</td><td>Soil</td><td>30</td><td>609</td></tr>
<tr><td>Organically grown sweet pepper</td><td>Soil</td><td>20</td><td>606</td></tr>
<tr><td>Lettuce</td><td>Soil</td><td>100</td><td>400</td></tr>
<tr><td>TOTAL</td><td></td><td></td><td>2,168 – 2,368</td></tr>
</table>
</td></tr>
<tr><td>2.5 How great a reduction in consumer demand</td><td>minimal</td><td>There are no indications that <i>M. enterolobii</i> would reduce consumer demands significantly. For other</td></tr>
</table>

is the pest likely to cause in the PRA area?	low	*Meloidogyne* species, the main impacts are related to producer profits (reduced yields and increased production costs) and environment (use of nematicides).
2.6 How important is environmental damage caused by the pest within its current area of distribution?	minimal low	There are no specific records referring to environmental damage caused by *M. enterolobii*.
2.7 How important is the environmental damage likely to be in the PRA area (see note for question 2.6)?	Minimal low	There is no known environmental damage reported.
2.8 How important is social damage caused by the pest within its current area of distribution?	Minimal medium	In the North East and South East of Brazil guava growers had to shift to another crop due to the presence of the pest as guava could not be grown anymore (Moreira *et al.* (2003) cited by Carneiro *et al.*, 2007) . No other record of social damage is known.
2.9 How important is the social damage likely to be in the PRA area?	minor medium	There is little information available to answer this question. It may limit the availability of organic vegetable in the PRA area or increase its production costs.
2.10 How likely is the presence of the pest in the PRA area to cause losses in export markets?	unlikely low	Based on an internet search the pest does not appear to be regulated as a species apart from the Republic of Korea. *M. enterolobii* has been on the NAPPO Alerts but this is not a list of regulated pests. It is not a regulated pest in any state of the USA so far. Some countries list *Meloidogyne* spp. as regulated pests but as other *Meloidogyne* species are present in the EPPO region this is not likely to result in more export losses.
2.11 How likely is it that natural enemies, already present in the PRA area, will not reduce populations of the pest below the economic threshold?	likely low	In general, *Meloidogyne* spp. have many natural enemies or antagonists (Kok, 2004). *Pasteuria penetrans* is a bacterial parasite of several *Meloidogyne* spp and occurs in Europe (CABI, 2007). However, in experiments, *P. penetrans* showed no or only poor pathogenicity to *M. enterolobii* (Brito *et al.*, 2004a; Carneiro *et al.*, 2004). **Note** In tests in Senegal, strains of *Arthrobotrys oligospora* reduced populations of *M. enterolobii* (Gueye *et al.*, 1997). Kok (2004) sees opportunities for biological control of *Meloidogyne* spp. with e.g. *Pochonia chlamydosporia* and *Paecilomyces lilacinus*.
2.12 How likely are control measures to disrupt existing biological or integrated systems for control of other pests or to have negative effects on the environment?	very likely/certain low	The use of soil fumigants has a large impact on the soil fauna since it kills many organisms present in the soil. It may also pollute the ground water quality. According to the Dutch “Centre for Agriculture and Environment” metam sodium and dazomet have a high toxicological impact on soil and ground water (http://milieumeetlat.nl). Soil fumigants are not included in the list of active substances in the EU (http://ec.europa.eu/food/plant/protection/evaluation/database_act_subs_en.htm ; website accessed 29/09/2009). In some EU-countries, metam sodium may be used as an “essential use” until 2014. Dazomet had been voluntarily withdrawn and should therefore be withdrawn from sale and use as of 31 December 2011 at the latest (EC decision no. 2008/934/EC). Nevertheless an application has been resubmitted for inclusion and it might be included in the future.

		The impact of non-chemical fumigants on the environment can also be substantial and several precautions need to be taken to minimize negative side effects when applying these agents (http://www.ctb.agro.nl).
2.13 How important would other costs resulting from introduction be?	minor low	Mainly research on host plants and control measures and advise to farmers.
2.14 How likely is it that genetic traits can be carried to other species, modifying their genetic nature and making them more serious plant pests?	unlikely low	There is no evidence that *M. enterolobii* can hybridise successfully with other nematode species
2.15 How likely is the pest to cause a significant increase in the economic impact of other pests by acting as a vector or host for these pests?	likely low	Members of the genus *Meloidogyne* are not known to transmit viruses. There are many references of Meloidogyne species interacting synergistically with fungi and bacteria (Evans *et al.*, 1993).
2.16 Referring back to the conclusion on endangered area (1.35) : Identify the parts of the PRA area where the pest can establish and which are economically most at risk.		**The pest can establish and cause economic damage in the whole EPPO region; more damage can be expected in the Mediterranean part of the region as the organism can establish also outdoors in addition to protected cultivation.**

Stage 2: Pest Risk Assessment - Section B: Degree of uncertainty and Conclusion of the pest risk assessment

2.17 Degree of uncertainty: list sources of uncertainty		Major uncertainties Origin of the pest (this is being investigated) Host range of the pest, in particular the importance of monocotyledon hosts (this is being investigated) and potato. How the pest was introduced in Brittany and Switzerland Transfer from ornamental plants (considered by the EWG to be the most likely pathway) to vegetable crops such as tomato and cucumber. Other uncertainties Distribution of the pest in the EPPO region Uncertainty on the prevalence and cultivation practices in nurseries or production areas in the countries where the pest is present. Temperature requirements of the pest (being investigated) and adaptability Actual use of root-knot nematode resistant cultivars (this is important given that is not an option to control this nematode) Crop rotation possibilities Interception of *Meloidogyne* species (could they be *M. enterolobii?)* Efficacy of nematicides against *M. enterolobii*

		Yield losses on crops of importance in the EPPO region Economic data (costs for control, crop losses…)
2.18 Conclusion of the pest risk assessment		**Probability of entry is considered high taking into account the likelihood of association and concentration of the pest at origin with the pathway, the volumes of trade and frequency, the likelihood to survive and to remain undetected. Almost all component of entry potential have been rated high.** **If imported infested plants are subsequently grown in a (greenhouse or field) nursery, this will aid transfer to a suitable host. If plants are for final consumers as pot plants the risk of transfer to suitable hosts is lower.** **The pest presents a risk of establishment in the EPPO region. Outdoor establishment is likely in the southern part of the region. The pest may also survive in the northern part of the region but temperature is less favourable for tropical root-knot nematodes. Establishment under protected conditions is possible in all parts of the region.** **Economic impact is likely to be higher than for other root-knot nematodes as it produces bigger galls (which can be correlated with reduction of crop yields). An important economic impact is noted in two glasshouses in Switzerland where it has been detected in tomato and cucumber production Also the ability of this nematode species to overcome root-knot nematode resistance genes in economically important crops may increase its economic impact.** **The pest is an appropriate candidate for the management stage.**

Stage 3: Pest Risk Management

3.1 Is the risk identified in the Pest Risk Assessment stage for all pest/pathway combinations an acceptable risk?	No	

3.2a Pathway 1 & 2:		**1 :Host plants for planting (including cuttings) with roots (with or without soil); 2:non-host plants with soil attached**
3.2 Is the pathway that is being considered a commodity of plants and plant products?	Yes	
3.12 Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest? (if yes, specify the measures in the box notes)	Yes	At least 30 out of 50 EPPO member countries (EU and associated countries) requirements exist in the legislation for the following commodities: Prohibitions Plants of *Solanaceae* intended for planting are prohibited from countries that are not European or Mediterranean countries. Plants of *Vitis* are also prohibited (from third countries to the EU)

		Specific requirement Specific requirements exist for Bonsais but repeated notifications of non compliance regarding nematode infestations in substrate indicate that the measures are not likely to prevent the introduction of the pest (although it is recognized that it may be linked to a lack of implementation by exporting countries). The same prohibitions apply in other countries such as Israel.
3.13 Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?	No	Galls may be visible but only for high levels of infestation. It also depends on the host plants and development stage of the nematode (see question 1.10).
3.14 Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?	No	Morphological identification is difficult. PCR or isozymes test exist and are reliable for identification of this species. Testing is in principle possible but was not considered to be practical by the Panel on phytosanitary measures due to the sampling regime that would have to be implemented.
3.15 Can the pest be reliably detected during post-entry quarantine?	No	A post-entry quarantine for plants for planting was not considered to be feasible by the Panel on phytosanitary measures for commercial import.
3.16 Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?	No	There is no reliable treatment of the consignment available.
3.17 Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment?	No (for host plants) Yes (for non host plants)	For host plants intended for planting this option is not possible as roots may be infested. For non-host plants the growing media can be removed.
3.18 Can infestation of the consignment be reliably prevented by handling and packing methods?	No	
3.19 Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?	No	
3.20 Can infestation of the commodity be reliably prevented by treatment of the crop?	No	No treatment will prevent infestation.
3.21 Can infestation of the commodity be reliably prevented by growing resistant cultivars?	No	
3.22 Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as	Yes	The plants should be grown for their whole life in protected conditions meeting the following growing conditions: artificial or disinfested growing medium should be used and no direct contact of the plant

screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?		growing media with the soil should be guaranteed plants for planting free from the nematode should be used as a start (for host plants only) exclusion of reinfestation by controlling irrigation water visual inspection of plants root. (for host plants only)
3.23 Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?	No	
3.24 Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?	No	Certification scheme may include place of production freedom for certain nematodes. This question is dealt with under "pest free place of production", see question " 3.28
3.25 Has the pest a very low capacity for natural spread?	Yes	The capacity of *M. enterolobii* for natural movement is very low and comparable to other *Meloidogyne* species; according to Tiilikkala *et al*. (1995), free-living second-stage juveniles can move 1-2 m at maximum per year. **Possible measures: pest-free place of production or pest-free area**
3.28 Can pest freedom of the crop, place of production or an area be reliably guaranteed?	Yes	Pest freedom can be verified by testing the site of production where the plants will be produced. This can be part of a certification scheme. The plants should be grown for their whole life in protected conditions meeting the following growing conditions: artificial or disinfested growing medium should be used and no direct contact of the plant growing media with the soil should be guaranteed plants for planting free from the nematode should be used as a start exclusion of reinfestation by controlling irrigation water visual inspection of plants root. The plants should have been grown in a pest-free area following ISPM No. 4 *requirements for the establishment of pest-free areas* or a pest-free place of production following ISPM No.10 *requirements for the establishment of pest-free places of production and pest-free production sites*. For pest free production sites, hygienic measures should be applied to avoid reinfestation.
3.29 Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?	No	The pest causes discrete symptoms (below ground) so it is not easy to detect. Given the host range surveillance would be very difficult. As explained in question 1.26 *M. enterolobii* is very likely to survive eradication programmes outdoors and moderately likely indoors.

3.31 Does each of the individual measures identified reduce the risk to an acceptable level?	Yes	Measures proposed reduce the risk, but the Panel on Phytosanitary measures commented that it was difficult to evaluate if this reduction was down to the acceptable level this should be decided at country level.
3.34 Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.		The measures are likely to have a major impact on trade but these are common measures requested for plants for planting worldwide.
3.35 Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.		The EWG considered this question was difficult to answer and was not in a position to give a judgement for the region. It has been evaluated for the Netherlands. Vermeulen *et al.* have made an estimate of the impact of *Meloidogyne* spp. that are already present in Dutch glasshouses. Based on this study, an estimation of the additional impact of *M. enterlobii* and the cost-effectiveness of measures was made: The conclusion for the Netherlands was that official phytosanitary measures are probably not cost-effective. Estimated costs for inspection, sampling and analyses and economic losses due to rejection of infested consignments were of the same order of magnitude as potential losses and additional control costs when the pest would become established in Dutch commercial glasshouses. The uncertainty of this analyses was, however, high since it is difficult to estimate the number of infested consignments and the potential costs (yield losses and control costs) for the various glasshouses crops (pers. comm. D.J. van der Gaag, NPPO of the Netherlands; Karssen *et al.* 2009). The crop area endangered in the EPPO region is, however, much larger than that of the Netherlands where about 2000 ha of glasshouse crops grown in soil are endangered and we expect that the measures will be cost-effective considering the potentially large economic impact of the pest in the EPPO area (see question 2.2). A main uncertainty is, however, the pest's current distribution in the EPPO region (see question 2.17) and costs of management measures may be high for those areas where the pest could already be present.
3.36 Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?	Yes	The measures envisaged interfere with trade but not unduly. It is not envisaged to close the pathway. Possible options include: ***For non-host plants with soil attached:*** Freedom from soil or The plants should have been grown in a pest-free area following ISPM No. 4 *requirements for the establishment of pest-free areas* or in a pest–free place of production following ISPM No.10 *requirements for the establishment of pest-free places of production and pest-free production sites.* For pest free place of production, hygienic measures should be applied to avoid reinfestation. ***For host plants for planting (including cuttings) with or without soil attached:*** The plants should be grown for their whole life in protected conditions meeting the following growing conditions:

		artificial or disinfested growing medium should be used plants for planting free from the nematode should be used as a start exclusion of reinfestation by controlling irrigation water no direct contact with the soil. visual inspection of plants root. The plants should have been grown in a pest-free area following ISPM No. 4 *requirements for the establishment of pest-free areas* or in a pest–free place of production following ISPM No.10 *requirements for the establishment of pest-free places of production and pest-free production sites.* For pest free place of production, hygienic measures should be applied to avoid re-infestation.

3.2a Pathway 3:		**Plant products that may have soil attached (such as tubers, bulbs or rhizomes)**
3.2 Is the pathway that is being considered a commodity of plants and plant products?	Yes	
3.12 Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?	Yes	The nematode can only be found in roots, not in tubers, bulbs or rhizomes Tolerance for soil exists for potato tubers but these are prohibited of import in most EPPO countries. Tolerances do not exist for other products in most phytosanitary regulations. In Israel, bulbs should be washed.
3.13 Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?	No	The pest cannot be detected in soil by visual inspection.
3.14 Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?	No	Testing residual soil on products is in principle possible but this is not practical.
3.15 Can the pest be reliably detected during post-entry quarantine?	No	Post entry quarantine for products is not practical
3.16 Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?	No	There is no reliable treatment of the consignment available.
3.17 Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment? (This question is not relevant for pest plants)	No	
3.18 Can infestation of the consignment be reliably prevented by handling and packing methods?	Yes	Tubers bulbs or rhizomes should be cleaned (brushing or washing) in order to be practically free from soil. **Possible measure: cleaning of the tubers, bulbs or rhizomes.**
3.19 Could consignments that may be infested be	No	

accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?		
3.20 Can infestation of the commodity be reliably prevented by treatment of the crop?	No	
3.21 Can infestation of the commodity be reliably prevented by growing resistant cultivars? (This question is not relevant for pest plants)	No	
3.22 Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?	Yes	Possible measure: specified growing conditions artificial or disinfested growing medium should be used exclusion of re-infestation by controlling irrigation water
3.23 Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?	No	
3.24 Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?	No	
3.25 Has the pest a very low capacity for natural spread?	Yes	The capacity of *M. enterolobii* for natural movement is very low and comparable to other *Meloidogyne* species; according to Tiilikkala *et al*. (1995), free-living second-stage juveniles can move 1-2 m at maximum per year. **Possible measures: pest freedom of the crop, or pest-free place of production or pest-free area** For pest free place of production, hygienic measures should be applied to avoid re-infestation.
3.28 Can pest freedom of the crop, place of production or an area be reliably guaranteed?	Yes	Pest freedom can be verified by testing the site of production where the plants will be produced.
3.29 Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?	No	The pest causes discrete symptoms (below ground) so it is not easy to detect. Given the host range surveillance would be very difficult.
3.31 Does each of the individual measures identified reduce the risk to an acceptable level?	Yes	

3.34 Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.		It is a common measure to request that products should be free from soil
3.35 Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.		Difficult to answer
3.36 Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?	Yes	Tubers, bulbs or rhizomes should be cleaned (brushing or washing) in order to be practically free from soil. Or Tubers, bulbs or rhizomes should have been grown in a pest-free area following ISPM No. 4 *requirements for the establishment of pest-free areas* or in a pest–free place of production following ISPM No.10 *requirements for the establishment of pest-free places of production and pest-free production sites.* For pest free place of production, hygienic measures should be applied to avoid reinfestation.
3.2a Pathway 4:		**Soil as such**
3.2 Is the pathway that is being considered a commodity of plants and plant products?	No	
3.12 Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?	Yes	Most EPPO member countries prohibit the import of soil as such.
3.13 Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?	No	The pest cannot be detected in soil by visual inspection.
3.14 Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?	No	Testing of soil is in principle possible but was not considered to be practical by the Panel on phytosanitary measures due to the sampling regime that would have to be implemented.
3.15 Can the pest be reliably detected during post-entry quarantine?	No	Post entry quarantine for products is not practical.
3.16 Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?	No	Soil can be sterilized but this is not practical for large consignments.
3.17 Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment? (This question is not relevant for pest plants)	No	
3.18 Can infestation of the consignment be	No	

reliably prevented by handling and packing methods?		
3.19 Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?	No	
3.20 Can infestation of the commodity be reliably prevented by treatment of the crop?	No	
3.21 Can infestation of the commodity be reliably prevented by growing resistant cultivars? (This question is not relevant for pest plants)	No	
3.22 Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?	No	
3.23 Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?	No	
3.24 Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?	No	
3.25 Has the pest a very low capacity for natural spread?	Yes	The capacity of *M. enterolobii* for natural movement is very low and comparable to other *Meloidogyne* species; according to Tiilikkala *et al*. (1995), free-living second-stage juveniles can move 1-2 m at maximum per year. **Possible measures: soil should originate from pest free production site, a pest-free place of production or pest-free area**
3.28 Can pest freedom of the crop, place of production or an area be reliably guaranteed?	Yes	Pest freedom can be verified by testing the site of production from where the soil will be taken.
3.29 Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or	No	The pest causes discrete symptoms (below ground) so it is not easy to detect. Given the host range surveillance would be very difficult.

economic or other impacts?		
3.31 Does each of the individual measures identified reduce the risk to an acceptable level?	Yes	
3.34 Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.		It is a common measure for soil.
3.35 Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.		Difficult to answer
3.36 Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?	Yes	The soil should originate from pest-free production site, a pest-free place of production or pest-free area.
3.2a Pathway 4:		**Soil attached to equipment and machinery.**
3.2 Is the pathway that is being considered a commodity of plants and plant products?	No	
3.10 Is the pathway being considered contaminated machinery or means of transport?	Yes	possible measures: cleaning of equipment and machinery
3.29 Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?	No	(see pathway 1)
3.31 Does each of the individual measures identified reduce the risk to an acceptable level?	Yes	
3.34 Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.		Cleaning of machinery/vehicles is a common measure worldwide.
3.35 Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.		No social or environmental consequences
3.36 Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with	Yes	Cleaning of equipment and machinery

international trade, are cost-effective and have no undesirable social or environmental consequences?		
3.2a Pathway 5		**Passengers**
3.2 Is the pathway that is being considered a commodity of plants and plant products?	No	
3.9 Is the pathway that is being considered the entry with human travellers?	Yes	Publicity to enhance public awareness on pest risks, fines or incentives. Treatments may also be possible (cleaning of shoes).
3.29 Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?	No	
3.31 Does each of the individual measures identified reduce the risk to an acceptable level?	Yes	
3.34 Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.		No interference with international trade.
3.35 Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.		It is very difficult to valuate the costs that would result from such measures. At the moment European countries do not have a system in place for passenger inspection so implementing this measure would definitely result in additional costs for importing countries.
3.36 Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?	Yes	
3.41 Consider the relative importance of the pathways identified in the conclusion to the entry section of the pest risk assessment		Host plants for planting (including cuttings) with roots (with or without soil) and non-host plants with soil attached are the most important pathway. In case importation of soil would be allowed this could also be an important pathway. The following pathways present a low risk. Tubers, bulbs, rhizomes. Equipment and machineries Passengers

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Appendix 1

The currently known (experimental) host plants for *M. enterolobii* include the following (those in bold are present in the EPPO region; *indicates species known to be introduced as an ornamental plant):

Scientific name	Common name	Reference(s)
Angelonia angustifolia*	Monkey face	Kaur *et al*., 2006
Acacia seyal	Whistling thorn	Duponnois *et al*., 1997
Acacia holosericea	Candelabra wattle	Duponnois *et al*., 1997
Ajuga reptans	Ajuga	Brito *et al*., 2004a
Apium graveolens var. dulce	Celery	Brito *et al*., 2004c
Beta vulgaris	Beet	Brito *et al*., 2004c
Bidens alba	Spanish needle	Brito *et al*., 2004c
Bidens pilosa	Spanish needle	Willers, 1997a
Brachychyton sp.		NPPO of the Netherlands, finding 2006
Brassica oleracea* var. *botrytis	Broccoli	Brito *et al*., 2004c
***Brugmansia* 'Sunray'**	Angel trumpet	Brito *et al*., 2004a
Cactus sp.*	Crimson Cactus	Brito *et al*., 2004c NPPO of the Netherlands, finding 1991
Callistemon citrinus	Bottlebrusth	Brito *et al*., 2004a
Callistemon viminalis	Weeping bottlebrush	Levin, 2005
Canavalia ensiformis	Horsebean	Brito *et al*., 2004c
Capsicum annuum	Bell pepper	Brito *et al*., 2004a; Yang & Eisenback, 1983, Kiewnick *et al*., 2009
Citrullis lanatus	Watermelon	Rammah & Hirschmann, 1988
Citrullis vulgaris	Watermelon	Yang & Eisenback, 1983
Clerodendrum ugandense*	Glorybower	Brito *et al*., 2004a
Coffea arabica	Coffee	Rodriguez *et al*., 1995a & b; Decker & Rodriguez Fuentes, 1989
Crotalaria juncea	Sunn hemp	Guimaraes *et al*., 2003
Cucumis sativus	Cucumber	Kiewnick *et al*., 2008
Cucurbita sp.	Pumpkin	Brito *et al*., 2004c
Enterolobium contortisiliquum	Pacara earpod tree	Yang & Eisenback, 1983
Faidherbia albida	Ana tree	Duponnois *et al*., 1997
Fatoua villosa	Hairy crabweed	Brito *et al*., 2004a
Ficus sp.	Ficus	NPPO of the Netherlands, finding 1999
***Gossypium hirsutum* L.**	Cotton	Yang & Eisenback, 1983
Ipomoea batatas	Sweet potato	Brito *et al*., 2004c
Lantana sp.	Lantana	Brito *et al*., 2004a
Ligustrum sp.		NPPO of the Netherlands, finding 2004
Lycopersicon esculentum	Tomato	Brito *et al*., 2004a, 2004b, 2004c; Guimaraes *et al*., 2003; Yang & Eisenback, 1983; Kiewnick *et al*., 2008
***Maranta arundinacea* L.**	arrowroot	Zhuo et al., 2009
Myrica cerifera	Wax myrtle	Brito *et al*., 2004a
Nicotiana tabacum	Tobacco	Rammah & Hirschmann, 1988, Yang & Eisenback, 1983
Ocimum sp.	Basil	Brito *et al*., 2004a
Petroselinum crispum	Parley	Brito *et al*., 2004c
Phaseolus vulgaris	Bean	Guimaraes *et al*., 2003
Poinsettia cyathophora	Wild poinsettia	Brito *et al*., 2004a
Psidium guajava	Guave	Torres *et al*., 2004 & 2005; Guimaraes *et al*., 2003; Brito *et al*., 2004a; Carneiro *et al*., 2001

Psidium guineense	Brazilian guave	Maranhao *et al*., 2003
Rosa sp.	Rose	NPPO of the Netherlands, finding 2006 + 2007
Solanum americanum	American black nightshade	Brito *et al*., 2004a
Solanum melongena	Egg plant	Brito *et al*., 2004a; Rammah & Hirschmann, 1988; Kiewnick, 2009 (unpublished)
Solanum tuberosum*	Potato	Rodriguez *et al.* (2003)
Solenostemon scutellarioides	Coleus	Levin 2005
Syagrus romanzoffiana	Queen palm	Levin, 2005
Syngonium sp.	Syngonium	NPPO of the Netherlands, finding 1993 + 1994
Tecomaria capensis	Cape honeysuckle	Brito *et al*., 2004a
Tibouchina 'Compacta'	Glory bush	Brito *et al*., 2004a
Tibouchina elegans	Glory bush	Brito *et al*., 2004a
Vigna unguiculata	Cowpea	Guimaraes *et al*., 2003
Vitis sp.	Grape	NPPO of the Netherlands, finding 2007

*never observed on tubers

The experimental host plants being present in the EPPO region for *M. enterolobii* include the following

Brassica oleracea **var.** ***sylvestris***	**Broccoli**	**Brito** ***et al*****., 2004c; Kiewnick, 2009 unpublished**
Brassica oleracea **var.** ***botrytis***	**Cauliflower**	**Kiewnick, 2009 unpublished (poor host)**
Brassica oleracea **L. convar.** ***Acephala***	**German Turnip**	**Kiewnick, 2009 unpublished (poor host)**
Brassica oleracea **L. convar.** ***capitata*** **L.**	**Chou de Milan (Wirsing)**	**Kiewnick, 2009 unpublished**
Brassica rapa ssp. pekinensis **(Lour.)**	**Chinese cabbage**	**Kiewnick, 2009 unpublished (poor host)**
Curcurbita pepo ssp. pepo	**Zucchini, Courgette**	**Kiewnick, 2009 unpublished**
Lactuca sativa L.	**Iceberg Lettuce**	**Kiewnick, 2009 unpublished**
Lactuca sativa var. crispa	**Baby leaf lettuce**	**Kiewnick, 2009 unpublished**
Lactuca sativa var.longifolia (LAM.) Helm	**Lattich**	**Kiewnick, 2009 unpublished**

Appendix 2

Distribution of *Meloidogyne enterolobii* Yang et Eisenback, 1983

Continent	Country	Location	Reference
Africa	**Senegal**	Bambylor	Diop, 1994; Trudgill *et al.*, 2000
		Keur Yerim	Diop, 1994
		Keur Ngoor	Diop, 1994
		Dakar	Diop, 1994
		Touba N'Diayc	Diop, 1994
		Mboro Nkage	Diop, 1994
		Fas Boye	Diop, 1994
		Mbodjene	Diop, 1994
		SE Gaouane	Diop, 1994
		ISRA St Louis	Diop, 1994
		Ndiol	Diop, 1994
		Ntiago	Diop, 1994
	South Africa	Nelspruit	Willers, 1997a
	Ivory Coast	*Man****	Fargette, 1987; Fargette *et al.*, 1994; Block *et al.*, 2002;
	Burkina Faso	*Bobo Dioulasso****	Fargette *et al.*, 1994; Trudgill *et al.*, 2000; Block *et al.*, 2002;
		*Ouagadougou****	Fargette *et al.*, 1994; Trudgill *et al.*, 2000; Blok *et al.*, 2002
	Malawi	Blantyre	Trudgill *et al.*, 2000
		Karonga	Trudgill *et al.*, 2000
		Kasungu	Trudgill *et al.*, 2000
		Lilongwe	Trudgill *et al.*, 2000
		Machinga	Trudgill *et al.*, 2000
		Mzuzu	Trudgill *et al.*, 2000
		Salima	Trudgill *et al.*, 2000
	Togo		Fargette, 1987
North America			
	USA		
		Florida	
		Alachua	Brito *et al.*, 2004(d); Brito *et al.*, 2007b
		Broward	Brito *et al.*, 2004(a); Brito *et al.*, 2007(b); Cetintas *et al.*, 2007; Cetintas *et al.*, 2008; Kaur *et al.*, 2007
		Dade	Brito *et al.*, 2004(a) Brito *et al.*, 2004(d); Brito *et al.*, 2007(b); Brito & Inserra, 2008; Cetintas *et al.*, 2008
		Gilchrist	Brito *et al.*, 2004(d)
		Hendry	Brito *et al.*, 2004(d); Brito *et al.*,

Continent	Country	Location	Reference
			2007(a) Centintas *et al.*, 2008
		Hillsborough	Levin, 1995
		Lee	Levin, 1995
		Martin	Brito *et al.*, 2004(a)
		Nassau	Brito *et al.*, 2004(a); Brito *et al.*, 2007(b)
		Palm Beach	Brito *et al.*, 2004(a); Brito *et al.*, 2007(a); Cetintas *et al.*, 2008
		Putman	Brito & Inserra, 2008
		St. Lucie	Brito *et al.*, 2004(d)
		Puerto Rico	
		Jobos	Ramah et Hirschmann, 1988;
		Isabella	Ramah et Hirschmann, 1988;
Central America			
	Cuba	Oriente	Decker & Rodriguez Fuentes, 1989, Rodrigues *et al.*, 1995 b; Rodrigues *et al.*, 2003
		Franco	Molinari *et al.*, 2005
	Guadeloupe***		IRD, 2006; Rammah & Hirschmann, 1988;
	Guatemala	Don Bosco, Coban	Decker & Rodriguez Fuentes, 1989; Carneiro *et al.*, 2000; Hernandes *et al.*, 2004
	Martinique	*Le Lamentin*	Carneiro *et al.*, 2000; IRD, 2006;
	Trinidad and Tobago	St George	Trudgill *et al.*, 2000
		St Andrew	Trudgill *et al.*, 2000
		Caroni	Trudgill *et al.*, 2000
		Nariva	Trudgill *et al.*, 2000
		Mayaro	Trudgill *et al.*, 2000
		Victoria	Trudgill *et al.*, 2000
		St Patrick	Trudgill *et al.*, 2000
		Tobago	Trudgill *et al.*, 2000
South America			
	Brazil	**Bahia**	
		Curaçá	Carneiro *et al.*, 2001
		Maniçoba	Carneiro *et al.*, 2001
		Ceará	
		Limoeiro do Norte	Torres *et al.* 2005
		Maranhão	
		Vila Maranhão	Silva *et al.* 2008
		Mato Grosso	
		Chapada dos Guimães	Almeida *et al.* 2008
		Paraná	
		Santa Mariana	Carneiro *et al.*, 2006
		Pernambuco	
		Petrolina	Carneiaro *et al.*, 2001

Continent	**Country**	**Location**	**Reference**
		Piaui	
		Distrito Irrigado	Silva *et al.*, 2008
		Rio Grande do Norte	
		Touros	Torres *et al.*, 2004
		Rio Grande do Sul	
		Roca sales	Gomes *et al.*, 2008
		Rio de Janeiro	Carneiro, 2003
		Campos dos Goyatacaces	Lima *et al.*, 2005
		São João da Barra	Lima *et al.*, 2003; Souza *et al.*, 2006
		Santa Catarina	
		Santa Rosa do Sul	Gomes *et al.*, 2008
		Içara	Gomes *et al.*, 2008
		São Paulo	
		Garça	Buenno *et al.*, 2007
		Pirajui	Carneiro *et al.*, 2006
		Santa Cruz do Rio Pardo	Carneiro *et al.*, 2006
		Campos Novos Paulista	Carneiro *et al.*, 2006
		Minas Gerais	Torres *et al.*, 2005
	Venezuela	**Lara State****	Perichi *et al.*, 2006
		Zulia State	
		Mara	Molinari *et al.*, 2005; Lugo *et al.*, 2005
Asia	**China**	Hainan	Yang & Eisenback, 1983; Xu *et al.*, 2004
	Vietnam	Southern Vietnam***	Iwahori *et al.*, 2009
Europe			
	France	Concarneau*	Blok *et al.*, 2002;
	Switzerland	**Aargau**$^+$	Kiewnick *et al.*, 2008
		Lucerne$^+$	Kiewnick *et al.*, 2008

*Plastic tunnel **Capital of the States ***no detailed information on location
$^+$ Glasshouse

Appendix 3. Crop production information relevant to the PRA text.

	Mean cucumber production area 2004-2006 (Ha)	Cucumber producer price per tonne 2004-2006	Cucumber production 2004-2006 (tonnes)	National cucumber production values 2004-2006 (national producer price x production)	Total national vegetable (including melon) harvest area (Ha)
EPPO country	**Mean**	**Mean (euros/tonne)**	**Mean national production (tonnes)**	**Mean national production value (EUR)**	**Mean harvest area (ha)**
Albania	2063	309	934	16697416	32108
Algeria	4005	87	1404	8247698	282019
Austria	442	417	481	16116689	13945
Azerbaijan	12887	178	4438	29440363	112707
Belarus	8588	512	3272	149651204	87535
Belgium	728	287	472	9065361	60100
Bosnia and Herzegovina	3130	222	1221	5273214	139163
Bulgaria	1621	361	829	23302356	58638
Croatia	541	340	452	3795965	22112
Cyprus	237	621	575	10416736	3918
Czech Republic	1364	504	858	13371044	17359
Denmark	116	299	278	5669294	9350
Estonia	320	561	555	4919450	4531
Finland	412	981	921	42419551	9176
France	773	750	857	100137177	389635
Germany	3099	289	1263	62279972	113050
Greece	2710	503	1305	78462525	135854
Hungary	1550	314	767	23689489	96329
Ireland	14	1184	950	1857734	6530
Israel	1750	303	825	40995965	55202
Italy	2357	449	1145	34366172	585843
Jordan	1515	154	628	21462886	34668
Kazakhstan	14514	282	5063	75024983	151709
Kyrgyzstan	3902	110	1388	6792024	46878
Latvia	1078	649	878	6682802	13437
Lithuania	794	537	694	3071997	19086
Malta	26				4579
Moldova	3122	125	1141	3570908	46015
Morocco	1080	162	489	8926399	207276
Netherlands	618	532	631	234482496	89767
Norway	108	1458	1201	20127155	6801
Poland	21766	277	7477	131702709	222825
Portugal	300	327	361	2407936	81238
Romania	12528	381	4480	63359854	290994
Russian Federation	90420	705	30703	984570959	941750
Serbia	8779	241	3119	5371905	157909
Slovakia	2332	457	1142	13573659	28152
Slovenia	138	388	356	1263003	3948
Spain	7766	380	2892	193947943	389962
Sweden	250	743	677	25765121	22380
Switzerland	83	1127	928	9438896	13615
Tunisia	1700	151	687	5616120	132685
Turkey	60000	280	20224	494832586	1065018
Ukraine	53503	437	18184	337695732	508023
United Kingdom	117	774	657	42997529	122409
Uzbekistan	10620				196277

	Mean tomato production area 2004-2006 (Ha)	Tomato producer price per tonne 2004-2006	Tomato production 2004-2006 (tonnes)	National production values 2004-2006 (national producer price x production)	Total national vegetable (including melon) harvest area (Ha)
EPPO country	**Mean**	**Mean (euros/tonne)**	**Mean national production (tonnes)**	**Mean national production value (EUR)**	**Mean harvest area (ha)**
Albania	6428	268	156284	42092579	32108
Algeria	40033	93	970626	89982141	282019
Austria	181	595	36755	22069378	13945
Azerbaijan	25413	44	434891	19218521	112707
Belarus	7913	575	239033	138482956	87535
Belgium	593	796	238503	189353083	60100
Bosnia and Herzegovina	3983	149	37031	5550293	139163
Bulgaria	8227	80	192343	14766948	58638
Croatia	1135	487	29319	14325750	22112
Cyprus	363	453	34012	15499359	3918
Czech Republic	1028	641	27291	18262521	17359
Denmark	47	861	18653	16052311	9350
Estonia	191	770	5349	4127772	4531
Finland	117	1098	37103	41026653	9176
France	5090	553	792947	437008571	389635
Germany	285	478	55814	26691219	113050
Greece	36237	443	1746045	773934457	135854
Hungary	4125	148	220737	31717308	96329
Ireland	27	1443	9667	14213311	6530
Israel	5340	270	444813	118749700	55202
Italy	135308	325	7073762	2310183632	585843
Jordan	10509	78	531329	42004310	34668
Kazakhstan	24389	143	498970	71942761	151709
Kyrgyzstan	9402	86	172106	15020322	46878
Latvia	997	733	7801	5762946	13437
Lithuania	294	579	1925	1088050	19086
Luxembourg	1	156	96	14467	46
Malta	333	445	14860	6559292	4579
Moldova	7171	68	87733	6047247	46015
Morocco	21530	126	1221347	154880415	207276
Netherlands	1416	844	663333	562618561	89767
Norway	33	1543	12263	19008556	6801
Poland	15353	118	611488	73009646	222825
Portugal	13571	361	1089729	397778265	81238
Romania	51638	412	930671	369460974	290994
Russian Federation	152310	668	2242873	1514938953	941750
Serbia	20947	156	189222	9893532	157909
Slovakia	3395	696	61815	43209742	28152
Slovenia	168	506	5557	2793931	3948
Spain	66496	454	4290934	1938840647	389962
Sweden	49	986	18024	17741375	22380
Switzerland	210	1191	27848	33322864	13615
Tunisia	25067	79	977667	77937395	132685
Turkey	265000	226	9781626	2220243896	1065018
Ukraine	93933	191	1456167	282849684	508023
United Kingdom	193	960	80643	77927080	122409
Uzbekistan	57353				196277

Appendix 4

Distribution of sandy soils such as arenosols (beige) and calcisols (yellow).