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SCIENTIFIC OPINION

Scientific Opinion on the pest categorisation of *Radopholus similis* (Cobb) Thorne and *Radopholus citrophilus* Huettel, Dickson and Kaplan[1]

EFSA Panel on Plant Health (PLH)[2,3]

European Food Safety Authority (EFSA), Parma, Italy

Abstract

The European Commission requested that the EFSA Panel on Plant Health perform a pest categorisation for *Radopholus similis* and *Radopholus citrophilus*. *R. similis* is regulated in Annex II, Part A, Section II of Council Directive 2000/29/EC as a harmful organism known to occur in the European Union (EU). *R. citrophilus* is regulated in Annex II, Part A, Section I of Council Directive 2000/29/EC as a harmful organism not known to occur in the EU. This pest characterisation applies only to *R. similis*, because *R. citrophilus* has been recognised as an invalid species designation and is considered as a junior synonym of *R. similis*. *R. similis* is a distinct taxonomic entity that is absent in the field production sites (citrus, bananas) of the risk assessment area and can cause significant losses in citrus production. Moreover, various susceptible hosts other than citrus species are present in the EU under climatic conditions that are suitable for the development of *R. similis*. The pest has a sporadic presence on ornamental plants (under protected cultivation) in a few EU countries. Plants for planting are a pathway for introduction and spread of *R. similis*. The pest is observed to cause impacts on ornamentals in some MSs and further impacts are expected should further spread happen in the EU.

Key words

banana, burrowing nematodes, citrus, pest categorisation, potato, *Radopholus citrophilus*, *Radopholus similis*

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2 Panel members: Richard Baker, Claude Bragard, Thierry Candresse, Gianni Gilioli, Jean-Claude Grégoire, Imre Holb, Michael John Jeger, Olia Evtimova Karadjova, Christer Magnusson, David Makowski, Charles Manceau, Maria Navajas, Trond Rafoss, Vittorio Rossi, Jan Schans, Gritta Schrader, Gregor Urek, Irene Vloutoglou, Stephan Winter and Wopke van der Werf. Correspondence: alpha@efsa.europa.eu

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BACKGROUND AS PROVIDED BY THE EUROPEAN COMMISSION

The current European Union plant health regime is established by Council Directive 2000/29/EC on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community (OJ L 169, 10.7.2000, p. 1).

The Directive lays down, amongst others, the technical phytosanitary provisions to be met by plants and plant products and the control checks to be carried out at the place of origin on plants and plant products destined for the Union or to be moved within the Union, the list of harmful organisms whose introduction into or spread within the Union is prohibited and the control measures to be carried out at the outer border of the Union on arrival of plants and plant products.

The Commission is currently carrying out a revision of the regulatory status of organisms listed in the Annexes of Directive 2000/29/EC. This revision targets mainly organisms which are already locally present in the EU territory and that in many cases are regulated in the EU since a long time. Therefore it is considered to be appropriate to evaluate whether these organisms still deserve to remain regulated under Council Directive 2000/29/EC, or whether, if appropriate, they should be regulated in the context of the marketing of plant propagation material, or be deregulated. The revision of the regulatory status of these organisms is also in line with the outcome of the recent evaluation of the EU Plant Health Regime, which called for a modernisation of the system through more focus on prevention and better risk targeting (prioritisation).

In order to carry out this evaluation, a recent pest risk analysis is needed which takes into account the latest scientific and technical knowledge on these organisms, including data on their agronomic and environmental impact, as well as their present distribution in the EU territory. In this context, EFSA has already been asked to prepare risk assessments for some organisms listed in Annex IIAII. The current request concerns 23 additional organisms listed in Annex II, Part A, Section II as well as five organisms listed in Annex I, Part A, Section I, one listed in Annex I, Part A, Section II and nine organisms listed in Annex II, Part A, Section I of Council Directive 2000/29/EC. The organisms in question are the following:

Organisms listed in Annex II, Part A, Section II:

- *Ditylenchus destructor* Thome
- *Circulifer haematoceps*
- *Circulifer tenellus*
- *Helicoverpa armigera* (Hübner)
- *Radopholus similis* (Cobb) Thome (could be addressed together with the HAI organism *Radopholus citrophilus* Huettel, Dickson and Kaplan)
- *Paysandisia archon* (Burmeister)
- *Clavibacter michiganensis* spp. *insidiosus* (McCulloch) Davis et al.
- *Erwinia amylovora* (Burr.) Winsl. et al. (also listed in Annex IIB)
- *Pseudomonas syringae* pv. *persicae* (Prunier et al.) Young et al.
- *Xanthomonas campestris* pv. *phaseoli* (Smith) Dye
- *Xanthomonas campestris* pv. *pruni* (Smith) Dye Ref. Ares(2014)970361 – 28/03/2014
- *Xyîophilus ampelinus* (Panagopoulos) Willems et al.
- *Ceratocystis fimbriata* f. sp. *platani* Walter (also listed in Annex IIB)
- *Cryphonectria parasitica* (Murrill) Barr (also listed in Annex IIB)
- *Phoma tracheiphila* (Petri) Kanchaveli and Gikashvili
- *Verticillium albo-atrum* Reinke and Berthold
- *Verticillium dahliae* Klebahn
- Beet leaf curl virus
- Citrus tristeza virus (European isolates) (also listed in Annex IIB)
- Grapevine flavescence dorée MLO (also listed in Annex IIB)

- Potato stolbur mycoplasma
- *Spiroplasma citri* Saglio et al.
- Tomato yellow leaf curl virus

Organisms listed in Annex I, Part A, Section I:

- *Rhagoletis cingulata* (Loew)
- *Rhagoletis ribicola* Doane
- Strawberry vein banding virus
- Strawberry latent C virus
- Elm phloem necrosis mycoplasm

Organisms listed in Annex I, Part A, Section II:

- *Spodoptera littoralis* (Boisd.)

Organisms listed in Annex II, Part A, Section I:

- *Aculops fuchsiae* Keifer
- *Aonidiella citrina* Coquillet
- Prunus necrotic ringspot virus
- Cherry leafroll virus
- *Radopholus citrophilus* Huettel, Dickson and Kaplan (could be addressed together with IIAII organism *Radopholus similis* (Cobb) Thome)
- *Scirtothrips dorsalis* Hendel
- *Atropellis* spp.
- *Eotetranychus lewisi* McGregor
- *Diaporthe vaccinii* Shaer.

TERMS OF REFERENCE AS PROVIDED BY THE EUROPEAN COMMISSION

EFSA is requested, pursuant to Article 29(1) and Article 22(5) of Regulation (EC) No 178/2002, to provide a pest risk assessment of *Ditylenchus destructor* Thome, *Circulifer haematoceps, Circulifer tenellus, Helicoverpa armigera* (Hübner), *Radopholus similis* (Cobb) Thome, *Paysandisia archon* (Burmeister), *Clavibacter michiganensis* spp. *insidiosus* (McCulloch) Davis et al., *Erwinia amylovora* (Burr.) Winsl. et al., *Pseudomonas syringae pv. persicae* (Prunier et al.) Young et al. *Xanthomonas campestris* pv. *phaseoli* (Smith) Dye, *Xanthomonas campestris* pv. *pruni* (Smith) Dye, *Xyîophilus ampelinus* (Panagopoulos) Willems *et al, Ceratocystis fimbriata* f. sp. *platani* Walter, *Cryphonectria parasitica* (Murrill) Barr, *Phoma tracheiphila* (Petri) Kanchaveli and Gikashvili, *Verticillium alboatrum* Reinke and Berthold, *Verticillium dahliae* Klebahn, Beet leaf curl virus, Citrus tristeza virus (European isolates), Grapevine flavescence dorée MLO, Potato stolbur mycoplasma, *Spiroplasma citri* Saglio *et al,* Tomato yellow leaf curl virus, *Rhagoletis cingulata* (Loew), *Rhagoletis ribicola* Doane, Strawberry vein banding virus, Strawberry latent C virus, Elm phloem necrosis mycoplasma, *Spodoptera littoralis* (Boisd.), *Aculops fuchsiae* Keifer, *Aonidiella citrina* Coquillet, Prunus necrotic ringspot virus, Cherry leafroll virus, *Radopholus citrophilus* Huettel Dickson and Kaplan (to address with the IIAII *Radopholus similis* (Cobb) Thome), *Scirtothrips dorsalis* Hendel, *Atropellis* spp., *Eotetranychus lewisi* McGregor *md Diaporthe vaccinii* Shaer., for the EU territory.

In line with the experience gained with the previous two batches of pest risk assessments of organisms listed in Annex II, Part A, Section II, requested to EFSA, and in order to further streamline the preparation of risk assessments for regulated pests, the work should be split in two stages, each with a specific output. EFSA is requested to prepare and deliver first a pest categorisation for each of these 38 regulated pests (step 1). Upon receipt and analysis of this output, the Commission will inform EFSA for which organisms it is necessary to complete the pest risk assessment, to identify risk reduction options and to provide an assessment of the effectiveness of current EU phytosanitary requirements (step 2). *Clavibacter michiganensis* spp. *michiganensis* (Smith) Davis *et al.* and

Xanthomonas campestris pv. *vesicatoria* (Doidge) Dye, from the second batch of risk assessment requests for Annex IIAII organisms requested to EFSA (ARES(2012)880155), could be used as pilot cases for this approach, given that the working group for the preparation of their pest risk assessments has been constituted and it is currently dealing with the step 1 "pest categorisation". This proposed modification of previous request would allow a rapid delivery by EFSA by May 2014 of the first two outputs for step 1 "pest categorisation", that could be used as pilot case for this request and obtain a prompt feedback on its fitness for purpose from the risk manager's point of view.

As indicated in previous requests of risk assessments for regulated pests, in order to target its level of detail to the needs of the risk manager, and thereby to rationalise the resources used for their preparation and to speed up their delivery, for the preparation of the pest categorisations EFSA is requested, in order to define the potential for establishment, spread and impact in the risk assessment area, to concentrate in particular on the analysis of the present distribution of the organism in comparison with the distribution of the main hosts and on the analysis of the observed impacts of the organism in the risk assessment area.

ASSESSMENT

1. Introduction

1.1. Purpose

This document presents a pest categorisation prepared by the EFSA Scientific Panel on Plant Health (hereinafter referred to as the Panel) for burrowing nematodes in response to a request from the European Commission. The pest characterisation applies only to *Radopholus similis* because *R. citrophilus* has been recognised as an invalid species designation and is considered as a junior synonym of *R. similis*.

1.2. Scope

The risk assessment area is the territory of the European Union (hereinafter referred to as the EU) with 28 Member States (hereinafter referred to as MSs), restricted to the area of application of Council Directive 2000/29/EC.

2. Methodology and data

2.1. Methodology

The Panel performed the pest categorisation for *R. similis* following the guiding principles and steps presented in EFSA Guidance on a harmonised framework for pest risk assessment (EFSA PLH Panel, 2010) and as defined in the International Standard for Phytosanitary Measures (ISPM) No 11 (FAO, 2004).

In accordance with the Guidance on a harmonised framework for pest risk assessment in the EU (EFSA, 2010), this work is initiated as result of the review or revision of phytosanitary policies and priorities. As explained in the background of the EC request, the objective of this mandate is to provide updated scientific advice to the European risk managers for their evaluation of whether these organisms listed in the Annexes of the Directive 2000/29/EC still deserve to remain regulated under Council Directive 2000/29/EC, or whether they should be regulated in the context of the marketing of plant propagation material, or be deregulated. Therefore, to facilitate the decision making process, in the conclusions of the pest categorisation, the Panel addresses explicitly each criterion for quarantine pests according to ISPM 11 (FAO, 2013) but also for regulated non-quarantine pests according to ISPM 21 (FAO, 2004) and includes additional information required as per the specific terms of reference received by the EC. In addition, for each conclusion the Panel provides a short description of its associated uncertainty.

Table 1 presents the ISPM 11 (FAO, 2013) and ISPM 21 (FAO, 2004) pest categorisation criteria against which the Panel provides its conclusions. It should be noted that the Panel's conclusions are formulated respecting its remit and particularly with regards to the principle of separation between risk assessment and risk management (EFSA founding regulation), therefore, instead of determining whether the pest is likely to have an unacceptable impact, the Panel will present a summary of the observed pest impacts. Economic impacts are expressed in terms of yield and quality losses and not in monetary terms, in agreement with the EFSA guidance on the harmonised framework for pest risk assessment (EFSA PLH Panel, 2010).

Table 1: International Standards for Phytosanitary Measures ISPM 11 (FAO, 2013) and ISPM 21 (FAO, 2004) pest categorisation criteria under evaluation

Pest categorisation criteria	ISPM 11 for being a potential quarantine pest	ISPM 21 for being a potential regulated non-quarantine pest
Identity of the pest	The identity of the pest should be clearly defined to ensure that the assessment is being performed on a distinct organism,	The identity of the pest is clearly defined

Pest categorisation criteria	ISPM 11 for being a potential quarantine pest	ISPM 21 for being a potential regulated non-quarantine pest
	and that biological and other information used in the assessment is relevant to the organism in question. If this is not possible because the causal agent of particular symptoms has not yet been fully identified, then it should have been shown to produce consistent symptoms and to be transmissible	
Presence (ISPM 11) or absence (ISPM 21) in the PRA area	The pest should be **absent from all or a defined part of the PRA area**	The pest is **present** in the PRA area
Regulatory status	If the pest is present but not widely distributed in the PRA area, it should be under official control or expected to be under official control in the near future	The pest is under official control (or being considered for official control) in the PRA area with respect to the specified plants for planting
Potential for establishment and spread in the PRA area	The PRA area should have ecological/climatic conditions including those in protected conditions suitable for the establishment and spread of the pest and, where relevant, host species (or near relatives), alternate hosts and vectors should be present in the PRA area	–
Association of the pest with the plants for planting and the effect on their intended use	–	Plants for planting are a pathway for introduction and spread of this pest
Potential for consequences (including environmental consequences) in the PRA area	There should be clear indications that the pest is likely to have an unacceptable economic impact (including environmental impact) in the PRA area	–
Indication of impact(s) of the pest on the intended use of the plants for planting	–	The pest may cause severe economic impact on the intended use of the plants for planting
Conclusion	If it has been determined that the pest has the potential to be a quarantine pest, the PRA process should continue. If a pest does not fulfil all of the criteria for a quarantine pest, the PRA process for that pest may stop. In the absence of sufficient information, the uncertainties should be identified and the PRA process should continue	If a pest does not fulfil all the criteria for an regulated non-quarantine pest, the PRA process may stop

In addition, in order to reply to the specific questions listed in the terms of reference, three issues are specifically discussed only for pests already present in the EU: the analysis of the present EU distribution of the organism in comparison with the EU distribution of the main hosts, the analysis of the observed impacts of the organism in the EU and the pest control and cultural measures currently implemented in the EU.

The Panel will not indicate in its conclusions of the pest categorisation whether to continue the PRA process as it is clearly stated in the terms of reference that at the end the pest categorisation the European Commission will indicate if further risk assessment work is required following their analysis of the Panel's scientific opinion.

2.2. Data

2.2.1. Literature search

An extensive literature search on *R. similis* was conducted at the beginning of the mandate. As the same species is sometimes mentioned under synonyms (section 3.1.1), the most frequent synonyms (*R. citrophilus*), together with the most applied common names, have been used for the extensive literature search. Further references and information were obtained from experts and from citations within the references.

2.2.2. Data collection

To complement the information concerning the current situation of the pest provided by the literature and online databases on pest distribution, damage and management, the PLH Panel sent a short questionnaire on the current situation at country level based on the information available in the EPPO PQR to the National Plant Protection Organization (NPPO) contacts of the 28 EU Member States, and of Iceland and Norway. Iceland and Norway are part of the European Free Trade Association (EFTA) and are contributing to EFSA data collection activities, as part of the agreements EFSA has with these two countries. A summary table on the pest status based on EPPO PQR and MS replies is presented in Table 4.

Information on the distribution of the main host plants was obtained from the EUROSTAT database. The EUROPHYT database was consulted, searching for pest-specific notifications on interceptions. EUROPHYT is a web-based network launched by the Directorate General for Health and Consumers (DG SANCO), and is a sub-project of PHYSAN (Phyto-Sanitary Controls) specifically concerned with plant health information. The EUROPHYT database manages notifications of interceptions of plants or plant products that do not comply with EU legislation.

3. Pest categorisation

3.1. Identity and biology of the pest

3.1.1. Taxonomy

Taxonomic position: Nematoda, Tylenchida, Pratylenchidae.

The burrowing nematode was described by Cobb in 1893 from diseased banana roots collected in Fiji in 1891 (Volcy, 2011). In the same publication, Cobb separately described males and females as two different new species (*Tylenchus similis* and *Tylenchus granulosus*, respectively) (Esser et al., 1984; Luc, 1987). While studying roots of diseased sugarcane in Hawaii, Cobb, in 1909, illustrated and described females and males of *Tylenchus biformis* but made no reference to his previous publications. Several years later, Cobb investigated nematodes collected from banana roots from Jamaica and concluded that *T. biformis* was actually *T. similis*. Consequently, a more detailed description of the species was published in 1915 (Thorne, 1961), which allowed Cobb to transfer *T. biformis* and *T. granulosus* to *T. similis* (Luc, 1987; Volcy, 2011).

After studying specimens from sugarcane in Hawaii and two females from roots of peppers from the East Indies, Thorne proposed, in 1949, a new genus, *Radopholus*, keeping *R. similis* as the type species (Esser et al., 1984; Volcy, 2011).

DuCharme and Birchfield (1956) reported from Florida the existence of two morphologically indistinguishable physiological host races of *R. similis*: the banana race, which caused toppling disease of bananas but did not attack citrus species, and the citrus race, which caused spreading decline of citrus species and also parasitised bananas. Both races have extended, overlapping host ranges that include ornamentals, agronomic crops and weeds (Esser et al., 1984; Inserra et al., 2005).

Although the races do not differ morphologically from each other (Esser et al., 1984), Huettel et al. (1984) recognised the banana and citrus races as two separate species (*R. similis* and *R. citrophilus*, respectively) on the basis of differences in enzymes and chromosome numbers (EPPO, 2008). Subsequently, this was rejected owing to (1) the proven ability of the two races to mate and produce offspring, and (2) a molecular analysis of their genomes that determined that they were not distinct species (Brooks, 2008). *R. citrophilus* has thus been recognised as an invalid species designation (Kaplan et al., 2000) and, based on karyotype identity, morphological and genetic identity and reproductive compatibility, it is now considered a junior synonym of *R. similis* (Vallete et al., 1998; Elbadri et al., 1999; Moens and Perry, 2009).

The organism under assessment is therefore recognised as a clear, distinguished taxonomic entity and the Panel refers to it with the following scientific name:

Name: *Radopholus similis* (Cobb) Thorne.

Synonyms: *Tylenchus similis* Cobb, *Tylenchus granulosus* Cobb, *Tylenchus acutocaudatus* Zimmerman, *Tylenchus biformis* Cobb, *Anguillulina similis* (Cobb) Goodey, *Rotylenchus similis* (Cobb) Filipjev, *Radopholus citrophilus* Huettel, Dickson and Kaplan. Other synonyms also exist but are no longer in use.

Common names: Burrowing nematode, banana burrowing nematode, citrus burrowing nematode, banana toppling disease nematode, pepper yellows nematode, slow wilt nematode (English), anguillule mineuse du bananier (French), nemátodo coco, nemátodo barrenador (Spanish).

3.1.1.1. Pest description and its origin

The burrowing nematode, *R. similis*, is an endoparasitic migratory nematode that can parasitise root tissues of host plants causing extensive cavitation and characteristic reddish-brown to black lesions that form cankers. There are more than 30 species in the genus *Radopholus*, which is assumed to be native to either the Indo-Malayan or the Australasia regions (Duncan and Moens, 2006). The most important hosts for *R. similis* all share a common centre of origin in the Indo-Malayan region, which suggests that this region is the most probably the region of origin (Marin et al., 1998). It is very likely that *R. similis* was introduced into Australia (Pattison et al., 1997; Stirling and Pattison, 2008; Tan et al., 2010). The burrowing nematode, *R. similis*, is the only *Radopholus* species of widespread economic importance (Duncan and Moens, 2006; Jones et al., 2013). It is found worldwide in tropical and sub-tropical areas of Africa, Asia, Australia, North and South America and many island regions (Sekora and Crow, 2002), and is considered one of the 10 most damaging plant-parasitic nematodes worldwide (Sasser and Freckman, 1987).

R. similis is a highly polyphagous nematode that can invade and feed in the cortex of roots of more than 365 plant species (Brooks, 2008; Moens and Perry, 2009; Babu et al., 2014). It is a migratory endoparasite that needs living hosts to survive and is able to complete its whole life cycle within the root cortex. However, vermiform adults and juveniles can also be present in the rhizosphere soil.

3.1.2. Biology of the pest

3.1.2.1. Life cycle

The burrowing nematode, *R. similis*, usually reproduces sexually, but sometimes also parthenogenetically. It is a migratory endoparasite that completes its life cycle within the root cortex. All larval stages and adult females of *R. similis* are infective and capable of penetrating the roots at any point of their length, but entry is usually behind the root tip (Duncan and Moens, 2006). Once entering the roots, the nematodes move intercellularly in the cortical parenchyma where they feed on the cytoplasm of nearby cells, causing lesions, cavities and root break-down (CABI, 2014). Each female lays, on average, four to five eggs each day (two each day in citrus species) for several weeks (Duncan and Moens, 2006; Brooks, 2008). At optimum temperatures, egg hatch occurs after two to three days on some hosts and after up to seven days in others (Duncan and Moens, 2006). After hatching from an egg, the emergent second-stage juvenile (J2) can migrate within the root and undergo a series of three moults through the third and fourth juvenile stages to reach the adult stage.

The reproduction of *R. similis* is temperature dependent (Elbadri et al., 2001) and the nematode is sensitive to low temperatures but thrives at higher temperatures and in moist soil conditions. In the temperature range 24–32 °C, the life cycle takes 18–25 days, whereas the life cycle lasts 18–20 days at 24–27 °C (Tarjan and O'Bannon, 1984; Gowen and Quénéhervé, 1990). Generally, this nematode does not reproduce at temperatures below 16–17 °C (Pinochet et al., 1995; Sarah et al., 1996) or above 33 °C (Sarah et al., 1996). However, populations exposed to lower temperatures for a long period could adapt to the cooler conditions and reproduce at 15 °C (Elbadri et al., 2001).

The burrowing nematodes require healthy root tissue for development and reproduction and remain within the root until forced to leave it because of overcrowding and decay caused by the invasion of secondary organisms. If host roots are not found, the population may decrease. In coconut, under field conditions, *R. similis* can survive for six months in moist soil at 27–36 °C, but can survive for only one month in dry soil at 29–39 °C. In glasshouses, the pest is reported to survive for 15 months in moist soil at 25.5–28.5 °C, and for up to three months in dry soil at 27–31 °C (Griffith and Koshy, 1990).

As burrowing nematodes cause extensive, deep lesions on roots and rhizomes, secondary infections by bacteria and fungi that further damage the root system are very common (Zunke, 1991; Babu et al., 2014). The root systems are consequently reduced, severely damaged and unable to absorb water and nutrients. This leads to a reduction of plant growth and development and consequently to severe economic losses. In the advanced stages of infection, the plant may become stunted and unthrifty, and frequently dies (Thorne, 1961).

3.1.2.2. Symptomatology

R. similis causes a decline of many plant species; however, the degree of host-plant susceptibility to this nematode is very variable, as one host may be severely damaged whereas damage to other hosts may be insignificant (Thorne, 1961). Symptoms caused by *R. similis* are most typical in bananas and plantain (*Musa* hybrids and cultivars), citrus (*Citrus* spp.) and black pepper (*Piper nigrum*) (Brooks, 2008).

Nematode damage to roots results in extensive cavities and characteristic reddish-brown to black lesions. The phloem and cambium may be completely destroyed, leaving nematode-filled spaces separating the stele from the cortex. External cracks may appear over the lesion (EPPO, 2008). Tissue rot occurs following secondary infections by fungi and bacteria (Duncan and Moens, 2006; Babu et al., 2014). Root systems of infested plants can be severely damaged, reduced and necrotic (Sekora and Crow, 2002); they are thus unable to absorb water and nutrients.

Although symptoms in citrus species caused by burrowing nematodes develop rapidly, aboveground symptoms are generally not very specific and include yellowing, stunting, a reduction in the number and size of leaves and fruit, a delay in flowering and overall sparse foliage of fruit trees. However, symptoms in bananas, plantain (*Musa* hybrids and cultivars) and black pepper (*Piper nigrum*) are more distinctive (Brooks, 2008).

The attack by *R. similis* on citrus trees is described as spreading decline. This disease was first recognised in Florida in the late 1920s, but it was not until 1953 that *R. similis* was recognised as the primary cause (O'Bannon, 1977). Infested trees show poor growth, dieback in the upper canopy, reduced tree size and reduced fruit and leaf numbers. Infested plants also have smaller leaves and more dead twigs than healthy plants owing to reduced uptake of water and nutrients (Kaplan and O'Bannon, 1985; EPPO, 2008).

In bananas, *R. similis* causes the so-called toppling disease (plants become uprooted and topple over), which is most dramatically expressed during banana fruiting, during strong winds or if heavy rains loosen the soil (Blake, 1972; Gowen and Quénéhervé, 1990; Brooks, 2008). Root damage and reduction leads to stunting of plants, lengthening of the production cycle, smaller fruit and decreased bunch weight. A shortened plant life may also occur in bananas and plantain (Brooks, 2008). Generally, infested plants do not respond well to fertilisation, irrigation or other cultural practices.

In black pepper (*Piper nigrum* L.), the burrowing nematode causes the so-called yellows disease or slow wilt disease of black pepper. This disease was first observed in the Indonesian island of Bangka (Thorne, 1961). The destruction of roots leads to reduced water and nutrient uptake. This is consequently expressed as aboveground symptoms of infested plants, such as pale yellow or whitish-yellow leaves that drop and then fall from the vine, slow plant growth, flower drop and vine dieback. Symptoms are more pronounced during dry periods, but, if moisture becomes available early in the disease (e.g. tropical monsoon rains), leaves are replaced and vines appear to recover (Koshy and Bridge, 1990; Brooks, 2008).

3.1.3. Intraspecific diversity

The most clear intraspecific diversity in *R. similis* is the existence of two races: the banana race, which attacks bananas but not citrus species, and the citrus race, which attacks both bananas and citrus species. Attempts to separate the banana and citrus races of *R. similis* by morphological and molecular methods (Huettel and Dickson, 1981; Huettel et al., 1983; Huettel and Yaegashi, 1988) have been unsuccessful (Kaplan and Opperman, 2000).

R. similis exhibits great morphological, physio-biological and molecular variability (Volcy, 2011). Biological diversity among *R. similis* populations was first demonstrated by studies based on morphology, cytogenetics, host range, and reproductive and damage potential, reviewed by Pinochet in 1988 (Elbadri et al., 2001). Great variability in pathogenicity and reproductive fitness among geographically separated populations of *R. similis* has been reported (Sarah et al., 1993; Fallas et al., 1995; Marin et al., 1998).

In order to study the genetic variation in *R. similis*, populations from many host plants and countries have been characterised by ribosomal DNA sequencing of the ITS and D2/D3 regions without detecting differences (Hahn et al., 1994; Fallas et al., 1996; Kaplan et al., 1996; Kaplan and Opperman, 1997). Hence, it seems that populations of *R. similis* are remarkably homogenous at these phylogenetically important genomic regions. This may relate to the fact that burrowing nematodes have been relatively recently disseminated worldwide from a single origin within the roots of major crops such as bananas (Marin et al., 1998; Duncan and Moens, 2006).

Although the genome of *R. similis* was reported to be highly conserved (Kaplan and Opperman, 2000; Kaplan et al., 2000), molecular variation between *R. similis* populations has been reported (Fallas et al., 1996; Elbadri et al., 2002). The same authors found evidence for the existence of two genomic groups based on cluster analysis of random amplified polymerase DNA profiles. The two groups spread independently and no relationship has been found between molecular and biological diversity. Under the influence of local environmental conditions, reproductive fitness and pathogenicity apparently evolved independently in both genomic groups.

Kaplan and O'Bannon (1985) demonstrated that one population of the citrus race of *R. similis* was able to reproduce on several resistant rootstocks, which demonstrated the existence of resistance-breaking biotypes. As knowledge of genetic variation within *R. similis* is essential for breeding programmes for resistance to this nematode (Costa et al., 2008), the interest in genetic variation at the intraspecific level and the possible existence of physiological races or biotypes in *R. similis* has increased (Kaplan and Gottwald, 1992; Hahn et al., 1994, 1996).

3.1.4. Detection and identification of the pest

The presence of burrowing nematodes can be established by sampling and extracting nematodes from roots, corms, tubers or the surrounding soil of host plants. Methods recommended to extract *R. similis* are as follows (EPPO, 2013):

- extraction from roots: direct examination or Baermann funnel/Oostenbrink dish;
- extraction from plant tissue: maceration and filtration or maceration and centrifugal flotation;
- extraction from soil samples: Baermann funnel/Oostenbrink dish or Oostenbrink/Seihorst elutriator or centrifugal flotation.

Radopholus spp. are small worm-like organisms measuring between 0.4 and 0.9 mm in length. Pharyngeal glands overlap the intestine dorsally and laterally. Females have fully developed anterior and posterior gonads. The genus is characterised by strong sexual dimorphism. Compared with the low head, the strongly sclerotised cephalic framework and the normal stylet and pharynx in females, the males have a higher and more off-set head and markedly reduced cephalic framework, stylet and pharynx (Siddiqi, 2000; Duncan and Moens, 2006). Species identification is mainly based on the examination of morphological and morphometric characteristics. *R. similis* can be relatively easily recognised using light microscopy (De Waele and Elsen, 2002). The female of *R. similis* can be distinguished from other species of the genus by (1) its dome-shaped head with three to four annules, (2) its stylet knobs of equal size, (3) its lateral field with four equally spaced incisures at mid-body, (4) the three incisures between the phasmid and tail tip, (5) both gonads having spermathecae of equal size and containing rod-like sperm, and (6) its elongate-conoid tail with a narrow rounded or indented terminus (De Waele and Elsen, 2002; Duncan and Moens, 2006; CABI, 2014). The bursa is coarsely crenate, enveloping about two-thirds of the tail. Provided males are present, the male characteristics are useful to distinguish *R. similis* form several *Radopholus* spp. (Duncan and Moens, 2006).

3.1.4.1. Conclusion

Having recognised that *R. similis* and *R. citrophilus* are not distinct species, *R. similis* now has an unambiguous taxonomical position, and an accepted and valid nomenclature. It can be accurately identified using light microscopy; however, the differentiation between banana and citrus races requires bio-tests.

3.2. Current distribution of *Radopholus similis*

3.2.1. Global distribution of *Radopholus similis*

The burrowing nematode, *R. similis*, is distributed worldwide in tropical and sub-tropical regions, including Africa, Asia, Central and South America, several Caribbean islands and the Pacific (Loof, 1991; Sekora and Crow, 2002; Jones et al., 2013) (Table 2 and Figure 1) and has also been found in glasshouses in temperate areas (O'Bannon, 1977). It has been found in the majority of banana-growing areas worldwide but is apparently still absent in many banana-producing countries, including Israel, the Canary Islands, the Cape Verde Islands, Cyprus, Crete, Mauritius, the highlands of East Africa and Taiwan (Marin et al., 1998). The citrus race of *R. similis* has a limited distribution, including Florida, parts of the Caribbean, Cote d'Ivoire and Guyana (Brooks, 2008).

Table 2: Current reports of burrowing nematodes (*R. similis*) outside the EU

Burrowing nematode	Country	References
R. similis	ASIA: Brunei Darussalam, India (Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Goa, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Nagaland, Odisha, Tamil Nadu, Uttar Pradesh, West Bengal), Indonesia (Sumatra), Lebanon, Malaysia (Peninsular), Oman, Pakistan, Philippines, Sri	EPPO (2008), CABI (2014)

Burrowing nematode	Country	References
	Lanka, Thailand, Yemen	
	AFRICA: Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Congo, Congo Democratic Republic, Côte d'Ivoire, East Africa, Egypt, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Madagascar, Malawi, Mauritius, Morocco, Mozambique, Nigeria, Réunion, Rwanda, Senegal, Seychelles, Somalia, South Africa, Sudan, Tanzania (Zanzibar), Uganda, Zambia, Zimbabwe	
	NORTH AMERICA: Canada (British Columbia), Mexico, USA (Florida, Hawaii, Louisiana, Texas)	
	CENTRAL AMERICA AND CARIBBEAN: Barbados, Belize, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, French West Indies, Grenada, Guadeloupe, Guatemala, Honduras, Jamaica, Martinique, Nicaragua, Panama, Puerto Rico, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines, Trinidad and Tobago, United States Virgin Islands, Windward Islands	
	SOUTH AMERICA: Bolivia, Brazil (Alagoas, Bahia, Ceará, Espírito Santo, Minas Gerais, Pernambuco, Rio de Janeiro, Santa Catarina, São Paulo), Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, Venezuela	
	EUROPE (excluding EU-28)	
	OCEANIA: American Samoa, Australia (Australian Northern Territory, New South Wales, Queensland, South Australia, Western Australia), Cook Islands, Fiji, French Polynesia, Guam, Federated States of Micronesia, New Caledonia, Niue, Norfolk Island, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga	

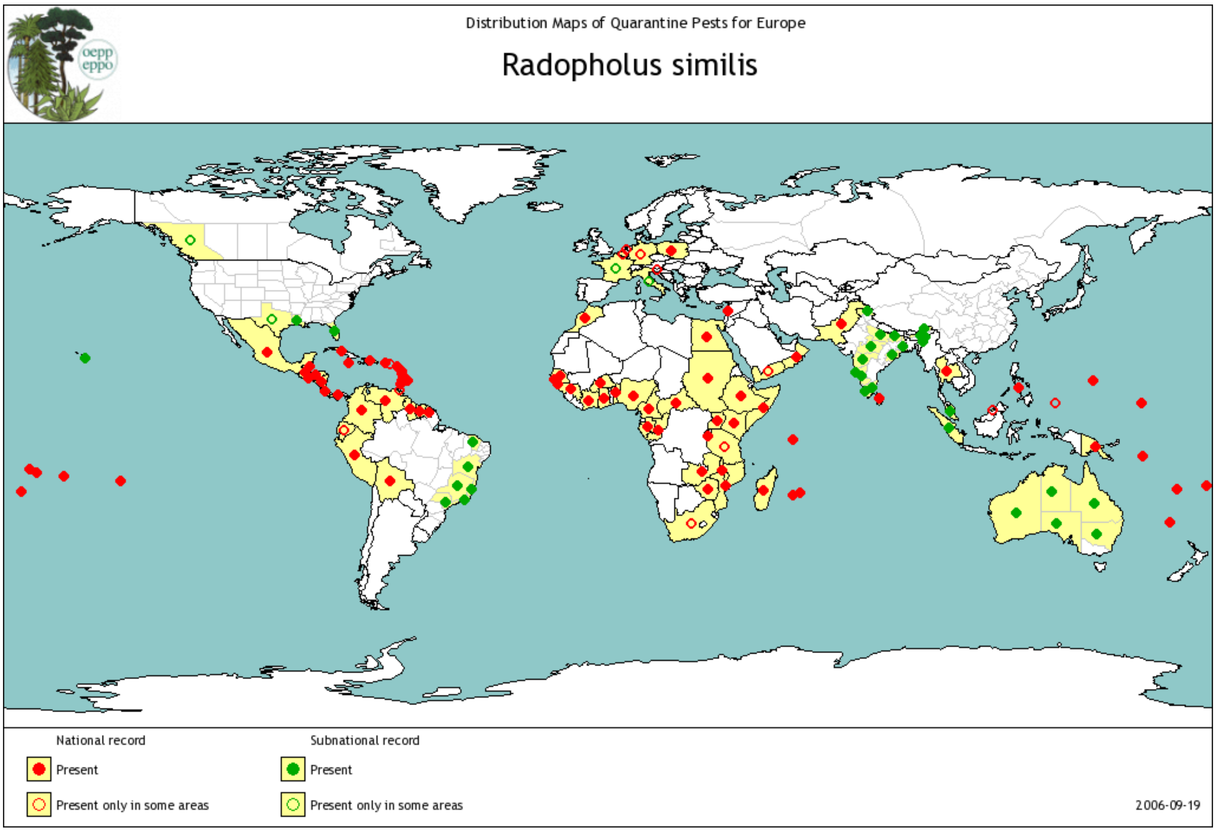

Figure 1: Global distribution of *R. similis* (extracted from EPPO PQR, version 5.3.1., accessed June 2014). Red circles represent pest presence as national records, green circles represent pest presence as sub-national records and empty circles represent transient pest presence (note that this figure combines information from different dates, some of which could be out of date).

There are 53 interceptions of *R. similis* by EU MSs from third countries reported in EUROPHYT (1995–2013). The majority of interceptions were made by the Netherlands and originated from South East Asian countries (Table 3).

Table 3: *R. similis* interceptions on consignments from third countries reported in EUROPHYT (data extracted from EUROPHYT, June 2014)

Year	Country	Origin	Intercepted commodity	Number
2013	Netherlands	Malaysia	*Musa* spp.	1
2013	Netherlands	Malaysia	*Anubias barteri*	1
2012	Netherlands	USA	*Anthurium* spp., *Colocasia* spp., *Heliconia* spp., *Philodendron* spp.	1
2010	Netherlands	Thailand	*Heliconia* spp.	1
2010	France	Thailand	*Anubias barteri*	1
2009	Netherlands	Sri Lanka	*Scindapsus* spp.	1
2009	Netherlands	Thailand	*Anubias* spp.	4
2009	France	Singapore	*Anubias barteri*	1
2009	Netherlands	Malaysia	*Anubias* spp.	1
2009	Netherlands	Singapore	*Anubias* spp.	1
2009	Netherlands	Thailand	*Anubias* spp.	5
2008	France	Thailand	*Anubias barteri*	1
2008	Netherlands	Malaysia	*Anthurium* spp.	1
2008	Netherlands	Costa Rica	*Heliconia* spp.	1
2008	France	Singapore	*Anubias barteri*	2
2008	Netherlands	Thailand	*Calathea* spp.	1

Year	Country	Origin	Intercepted commodity	Number
2008	Netherlands	Thailand	*Anubias* spp.	2
2008	Netherlands	Malaysia	*Anubias barteri*	1
2007	Netherlands	USA	*Anubias* spp.	1
2007	Netherlands	Thailand	*Anubias* spp.	2
2007	France	Singapore	*Anubias barteri*	1
2005	France	Singapore	*Anubias barteri*	1
2005	Germany	Philippines	*Cryptocoryne* spp.	1
2005	France	Sri Lanka	*Areca* spp., *Caryota* spp., *Livistona* spp.	1
2003	France	Cote d'Ivoire	*Syngonium* spp.	3
2003	France	Cote d'Ivoire	*Schefflera* spp.	3
2003	France	Cote d'Ivoire	*Pothos* spp.	2
2003	Netherlands	Israel	*Philodendron* spp.	1
2003	Germany	Singapore	*Acorus* spp.	1
2002	Netherlands	Thailand	*Anthurium* spp.	1
2001	Netherlands	Sri Lanka	*Scindapsus aureus*	1
1998	Netherlands	Sri Lanka	*Musa* spp.	1
1998	Netherlands	Brazil	*Maranta* spp.	1
1997	Netherlands	Jamaica	*Calathea* spp.	2
1997	Netherlands	Sri Lanka	*Philodendron* spp.	1
1996	Netherlands	Malaysia	*Heliconia* spp.	1
1995	Netherlands	Costa Rica	*Calathea* spp.	1

3.2.2. Distribution of *Radopholus similis* in the EU

The pest is currently locally established on ornamental plants under protected cultivation in Belgium, France and the Netherlands (low prevalence) (Table 4). It was officially eradicated from Denmark, Portugal (Madeira) and Sweden and was intercepted in Germany (EPPO check diagnostic protocol; CABI, 2014).

In conclusion, the pest is sporadically present in greenhouses of some EU MSs and outbreaks are usually severe.

Table 4: The current distribution of *R. similis* in the risk assessment area, based on answers received from the 28 EU Member States, Iceland and Norway (or based on EPPO PQR, if no answers were received)

Member State*	Current situation
Austria	Absent, no pest records
Belgium	Present, restricted distribution (only under protected cultivation)
Bulgaria	Absent, no pest records
Croatia	Absent, no pest records
Cyprus	Absent, no pest records
Czech Republic	Absent, no pest records
Denmark	Absent, pest eradicated
Estonia	Absent, no pest records
Finland	Absent, no pest records
France	Present, restricted distribution
Germany	Absent, intercepted only
Greece	No data (EPPO PQR)
Hungary	Absent, no pest records
Ireland	No data (EPPO PQR)
Italy	Present, restricted distribution (EPPO PQR)
Latvia	No data (EPPO PQR)

Member State*	Current situation
Lithuania	No data (EPPO PQR)
Luxembourg	No data (EPPO PQR)
Malta	Absent, no pest records
Netherlands	Present, only in restricted cultivation, at low prevalence
Poland	Absent, pest eradicated
Portugal	Absent, pest eradicated
Romania	No data (EPPO PQR)
Slovakia	Absent, no pest records
Slovenia	Absent, pest records invalid
Spain	Absent, no pest records
Sweden	Absent, pest eradicated
United Kingdom	Absent, pest eradicated
Iceland	No data (EPPO PQR)
Norway	No data (EPPO PQR)

EPPO PQR, European and Mediterranean Plant Protection Organization Plant Quarantine Retrieval.
*When no information was made available to EFSA, the pest status in the EPPO PQR (2014) was used.

There are no interceptions of *R. similis* from EU MSs reported in EUROPHYT up to 2013, apart from an interception from the Canary Islands (Spain) to Germany on *Anubias* spp. in 2004.

3.3. Regulatory status

R. similis is considered the most damaging nematode pest of citrus species and is commonly listed as a quarantine organism. As a restricted organism, it is regulated in more than 50 countries (data include both *R. similis* and *R. citrophilus*) (Hockland et al., 2006). Despite the fact that *R. citrophilus* has been recognised as an invalid species designation and is considered as a junior synonym of *R. similis*, both *R. similis* and *R. citrophilus* are still listed in the EU legislation.

3.3.1. Legislation addressing *Radopholus similis* and *Radopholus citrophilus* (Council Directive 2000/29/EC)

R. similis is regulated as a harmful organism in the EU and listed in Council Directive 2000/29/EC (Table 5).

Table 5: Legislation addressing *R. similis* (Council Directive 2000/29/EC)

Annex II, Part A—Harmful organisms whose introduction into, and spread within, all Member States shall be banned if they are present on certain plants or plant products	
Section II—Harmful organisms known to occur in the Community and relevant for the entire Community	
(a) Insects, mites and nematodes, at all stages of their development	
Species	**Subject of contamination**
7. *Radopholus similis* (Cobb) Thorne	Plants of Araceae, Marantaceae, Musaceae, *Persea* spp. and Strelitziaceae, rooted or with growing medium attached or associated

R. citrophilus is regulated as a harmful organism in the EU and listed in Council Directive 2000/29/EC (Table 6).

Table 6: Legislation addressing *R. citrophilus* (Council Directive 2000/29/EC)

Annex II, Part A—Harmful organisms whose introduction into, and spread within, all Member States shall be banned if they are present on certain plants or plant products
Section I—Harmful organism not known to occur in the Union and relevant for the entire Union

(a) Insects, mites and nematodes, at all stages of their development	
Species	**Subject of contamination**
23. *Radopholus citrophilus* Huettel, Dickson and Kaplan	Plants of *Citrus* L., *Fortunella* Swingle, *Poncirus* Raf. and their hybrids, other than fruit and seeds, and plants of Araceae, Marantaceae, Musaceae, *Persea* spp. and Strelitziaceae, rooted or with growing medium attached or associated

3.3.2. Legislation addressing hosts of *Radopholus similis* and *Radopholus citrophilus* (Council Directive 2000/29/EC)

R. similis and *R. citrophilus* are polyphagous pests and have many more potential hosts than those for which they are regulated in AIIAII and AIIAI, respectively (see section 3.4.1). It is also important to mention that other specific commodities (e.g. soil and growing media) could be pathways of introduction of the pest in the risk assessment area.

In Table 7, the Panel lists only the legislative articles of Annex III, IV and V of Council Directive 2000/29/EC that are relevant for the host plants and commodities regulated for *R. similis* and *R. citrophilus* in Annex IIAII and Annex IIAI, respectively.

Table 7: Legislation addressing hosts of *R. similis* and *R. citrophilus* (Council Directive 2000/29/EC)

Annex III, Part A—Plants, plant products and other objects the introduction of which shall be prohibited in all Member States	
Description	**Country of origin**
14. Soil and growing medium as such, which consists in whole or in part of soil or solid organic substances such as parts of plants, humus including peat or bark, other than that composed entirely of peat	Turkey, Belarus, Estonia, Latvia, Lithuania, Moldavia, Russia, Ukraine and third countries not belonging to continental Europe, other than the following: Cyprus, Egypt, Israel, Libya, Malta, Morocco, Tunisia
16. Plants of *Citrus* L., *Fortunella* Swingle, *Poncirus* Raf. and their hybrids, other than fruit and seeds	Third countries
Annex IV, Part A—Special requirements which must be laid down by all Member States for the introduction and movement of plants, plant products and other objects into and within all Member States	
Section I—Plants, plant products and other objects originating outside the Community	
Plants, plant products and other objects	**Special requirements**
18. Plants of *Citrus* L., *Fortunella* Swingle, *Poncirus* Raf. and their hybrids, other than fruit and seeds and plants of Araceae, Marantaceae, Musaceae, *Persea* spp. and Strelitziaceae, rooted or with growing medium attached or associated	Without prejudice to the prohibitions applicable to the plants listed in Annex III(A)(16), where appropriate, official statement that: (a) the plants originate in countries known to be free from *R. citrophilus* Huettel et al. and *R. similis* (Cobb) Thorne; (b) representative samples of soil and roots from the place of production have been subjected, since the beginning of the last complete cycle of vegetation, to official nematological testing for at least *R. citrophilus* Huettel et al. and *R. similis* (Cobb) Thorne and have been found, in these tests, free from those harmful organisms
34. Soil and growing medium attached to or associated with plants, consisting in whole or in part of soil or solid organic substances such as parts of plants, humus including peat or bark or any solid inorganic substance, intended to sustain the vitality of the plants, originating in: - Turkey; - Belarus, Estonia, Latvia, Lithuania,	Official statement that: (a) the growing medium, at the time of planting, was: - either free from soil, and organic matter; - found free from insects and harmful nematodes and subjected to appropriate examination or heat treatment or fumigation to ensure that it was free from other harmful organisms; or subjected to appropriate heat treatment or fumigation to

Moldavia, Russia, Ukraine; - non-European countries other than Cyprus, Egypt, Israel, Libya, Malta, Morocco, Tunisia	ensure freedom from harmful organisms; and (b) since planting: - either appropriate measures have been taken to ensure that the growing medium has been maintained free from harmful organisms, or within two weeks prior to dispatch, the plants were shaken free from the medium leaving the minimum amount necessary to sustain vitality during transport, and, if replanted, the growing medium used for that purpose meets the requirements laid down in (a)
Section II—Plants, plant products and other objects originating in the Community	
Plants, plant products and other objects	**Special requirements**
11. Plants of Araceae, Marantaceae, Musaceae, *Persea* spp. and Strelitziaceae, rooted or with growing medium attached or associated	Official statement that: (a) no contamination by *R. similis* (Cobb) Thorne has been observed at the place of production since the beginning of the last complete cycle of vegetation;Or (b) soil and roots from suspected plants have been subjected since the beginning of the last complete cycle of vegetation to official nematological testing for at least *R. similis* (Cobb) Thorne and have been found, in these tests, free from that harmful organism
Annex V—Plants, plant products and other objects which must be subject to a plant health inspection (at the place of production if originating in the Community, before being moved within the Community—in the country of origin or the consignor country, if originating outside the Community) before being permitted to enter the Community	
Part A—Plants, plant products and other objects originating in the Community	
Section I—Plants, plant products and other objects which are potential carriers of harmful organisms of relevance for the entire Community and which must be accompanied by a plant passport	
1. Plants and plant products	
1.4. Plants of *Fortunella* Swingle, *Poncirus* Raf. and their hybrids and *Vitis* L., other than fruit and seeds	
1.5. Without prejudice to point 1.6, plants of *Citrus* L. and their hybrids other than fruit and seeds	
1.6. Fruits of *Citrus* L., *Fortunella* Swingle, *Poncirus* Raf. and their hybrids with leaves and peduncles	
2. Plants, plant products and other objects produced by producers whose production and sale is authorised to persons professionally engaged in plant production, other than those plants, plant products and other objects which are prepared and ready for sale to the final consumer, and for which it is ensured by the responsible official bodies of the Member States, that the production thereof is clearly separate from that of other products	
2.3. Plants of Araceae, Marantaceae, Musaceae, *Persea* spp. and Strelitziaceae, rooted or with growing medium attached or associated	
Part B—Plants, plant products and other objects which must be subject to a plant health inspection, originating in territories other than those referred in Part A	
I. Plants, plant products and other objects which are potential carriers of harmful organisms of relevance for the entire Community	
7. (a) Soil and growing medium as such, which consists in whole or in part of soil or solid organic substances such as parts of plants, humus including peat or bark, other than that composed entirely of peat (b) Soil and growing medium, attached to or associated with plants, consisting in whole or in part of material specified in (a) or consisting in part of any solid inorganic substance, intended to sustain the vitality of the plants, originating in: - Turkey; - Belarus, Georgia, Moldavia, Russia, Ukraine; - non-European countries, other than Algeria, Egypt, Israel, Libya, Morocco, Tunisia	

3.3.3. Legislation addressing the hosts in the marketing directives

Citrus spp., *Pyrus* spp. and *Fragaria* spp. are potential hosts of *R. similis* that are explicitly mentioned in marketing directives (Council Directive 2008/90/EC).

3.4. Elements to assess the potential for establishment and spread in the EU

3.4.1. Host range

R. similis is a highly polyphagous parasite and is able to attack a wide range of agronomic and horticultural crops as well as many weeds (O'Bannon, 1977). To date, this nematode has been observed in tropical and sub-tropical regions infecting more than 365 plant species belonging to several families (e.g. Rutaceae, Arecaceae, Araceae, Marantaceae, Musaceae, Poaceae, Brassicaceae, Rubiaceae, Solanaceae, Piperaceae, Zingiberaceae, Theaceae, Bromeliaceae, Lauraceae, Fabaceae, Apiaceae, Dioscoraceae, Schisandraceae, Pinaceae, Rosaceae) (Tables 8 and 9) (Brooks, 2008; EPPO, 2008; Moens and Perry, 2009; CABI, 2014).

Table 8: The most important hosts of *R. similis* (Chitambar, 1997; CABI, 2014)

Common name	Latin name
Pineapple	*Ananas comosus*
Flamingo flower	*Anthurium andreanum*
Groundnut	*Arachis hypogaea*
Betelnut palm	*Areca catechu*
Calathea	*Calathea* spp.
Tea	*Camellia sinensis*
Neanthe bella palm	*Chamaedorea elegans*
Butterfly palm	*Chrysalidocarpus lutescens*
Citrus	*Citrus* spp.
Coconut	*Cocos nucifera*
Arabica coffee	*Coffea arabica*
Robusta coffee	*Coffea canephora*
Coffee	*Coffea* spp.
Taro	*Colocasia esculenta*
Turmeric	*Curcuma longa*
Carrot	*Daucus carota*
Dumb cane	*Dieffenbachia* spp.
Yam	*Dioscorea* spp.
Water yam	*Dioscorea alata*
Ginger lily	*Hedychium* spp.
Lady's fingers	*Hibiscus esculentus*
Star anise	*Illicium verum*
Hairy indigo	*Indigofera hirsuta*
Sweet potato	*Ipomea batatas*
Litchi	*Litchi chinensis*
Prayer plant	*Maranta* spp.
Monstera	*Monstera* spp.
Banana	*Musa* spp.
Manila hemp	*Musa textilis*
Plantain	*Musa × paradisiacal*
Peperomia	*Peperomia* spp.
Avocado	*Persea americana*
Philodendron	*Philodendron* spp.
Khasya pine	*Pinus kesiya* (habitat association)
Betel pepper	*Piper betle*
Black pepper	*Piper nigrum*
Bitter orange	*Poncirus trifoliata*
Pear	*Pyrus* spp.
Sugarcane	*Saccharum officinarum*
Devil ivy	*Scindapsus* spp.
Tomato	*Solanum lycopersicum*
Black nightshade	*Solanum nigrum*

Common name	Latin name
Peace lily	*Spathiphyllum* spp.
Tri-leaf wonder	*Syngonium* spp.
Lipstick plant	*Trichosporium* spp.
Maize	*Zea mays*
Ginger	*Zingiber officinale*

Table 9: Crops that are also reported to be susceptible to *R. similis* (Christie, 1959; Uchida et al., 2003; Nemaplex, 2014)

Common name	Latin name
Okra	*Abelmoschus esculentus*
Onion	*Allium cepa*
Bamboo	*Bambusa* spp.
Beet	*Beta vulgaris*
Cabbage	*Brassica oleracea*
Pepper	*Capsicum annuum*
Watermelon	*Citrullus lanatus*
Muskmelon	*Cucumis melo*
Pumpkin	*Cucurbita* spp.
Strawberry	*Fragaria ananassa*
Soybean	*Glycine max*
Lettuce	*Lactuca sativa*
Mango	*Mangifera indica*
Lucerne	*Medicago sativa*
Rice	*Oryza sativa*
Bean	*Phaseolus* spp.
Guava	*Psidium* spp.
Radish	*Raphanus sativus*
Castor bean	*Ricinus communis*
Rye	*Secale cereale*
Aubergine	*Solanum melongena*
Sorghum	*Sorghum bicolor*
Bird of paradise	*Strelitzia reginae*
Clover	*Trifolium* spp.

3.4.2. EU distribution of main hosts

R. similis has a wide host range and can cause serious damage to many important fruit (oranges, mandarins, lemons, grapefruit, bananas, plantain) and ornamental plants (e.g. *Anthurium*, *Philodendron* and *Calathea*), many of which are intensively grown in the risk assessment area. The host range also includes a number of crop species, such as aubergine, bean, beet, broccoli, cabbage, clover, lettuce, lucerne, onion, pepper, pumpkin, radish, rye, sorghum, soybean, strawberry and many others that are widely grown either outdoors or indoors all over Europe.

Citrus spp. are grown in most of the Mediterranean area (Greece, Italy, Morocco, Spain, Turkey, etc.). In the EU, *Citrus* spp. are grown in eight countries: Spain, Italy, Greece, Portugal, Cyprus, France, Croatia and Malta (Table 10). The total citrus production area in the EU (EU-28) in 2007 is estimated at roughly 500 000 ha. The major citrus-producing countries are Spain (314 908 ha), Italy (112 417 ha) and Greece (44 252 ha), with more than 95 % of the total citrus production in the EU. Other citrus-producing countries are Portugal (16 145 ha), Cyprus (3 985 ha), France (1 705 ha), Croatia (1 500 ha) and Malta (193 ha) (EUROSTAT, 2014).

The major citrus crop is sweet orange, the most cultivated fruit in the EU after apples. Total production of oranges in the EU in 2012–2013 was about 5.6 million tonnes, of which more than 80 % was produced in Spain and Italy. The total EU production of easy peelers (mandarins) for 2012–2013 is estimated at 2.9 million tonnes. More than 92 % of mandarins originated from Spain and Italy. In

2012–2013, the EU also produced 1.15 million tonnes of lemons and 91 000 tonnes of grapefruit (FreshPlaza, 2014).

Citrus nursery production is less precisely documented. Estimations from the mid-2000s suggest a nursery production dedicated to fruit and ornamental plant production of approximately 19 million trees annually (Spain 10 665 000, Italy 5 771 000, Portugal 844 000, Greece 826 000 and France 819 000). These estimates were calculated based on a rate of tree renewal of 7.5 %. Moreover, citrus species are commonly available in these countries in city streets as well as in public and private gardens (EFSA PLH Panel, 2014a).

In the EU, bananas (*Musa* spp.) are mostly grown in Spain (the Canary Islands), France (Guadeloupe and Martinique), Cyprus, Greece (Crete and Laconia) and Portugal (Madeira, the Azores and the Algarve). The total production of bananas in the EU in 2009 was about 600 000 tonnes (Anonymous, 2012). It is estimated that the production of bananas grown within the EU satisfied about 12.6 % of the total EU consumption in 2012 (FAO, 2014).

Table 10: Area of production in hectares for citrus species in 2007 as extracted from the EUROSTAT database (February 2013; data from EFSA PLH Panel, 2014b). Countries with non-null production are highlighted in bold.

Country	Oranges	Lemons	Small-fruited citrus species	All citrus species
Austria	0	0	0	0
Belgium	0	0	0	0
Bulgaria	0	0	0	0
Croatia	200	100	1 200	1 500
Cyprus	1 554	665	1 766	3 985
Czech Republic	0	0	0	0
Denmark	0	0	0	0
Estonia	0	0	0	0
Finland	0	0	0	0
France	28	22	1 654	1 705
Germany	0	0	0	0
Greece	32 439	5 180	6 631	44 252
Hungary	0	0	0	0
Ireland	0	0	0	0
Italy	73 785	16 633	21 997	112 417
Latvia	0	0	0	0
Lithuania	0	0	0	0
Luxembourg	0	0	0	0
Malta	–	–	–	193
Netherlands	0	0	0	0
Poland	0	0	0	0
Portugal	12 416	494	3 235	16 145
Romania	0	0	0	0
Slovakia	0	0	0	0
Slovenia	0	0	0	0
Spain	158 824	39 859	116 225	314 908
Sweden	0	0	0	0
United Kingdom	0	0	0	0
EU-28	279 246	62 953	152 708	495 105

–: data not available.

3.4.3. Analysis of the potential pest distribution in the EU

3.4.3.1. Availability of suitable host plants (outdoors, in protected cultivation or both)

Citrus species, many important ornamental crops and other susceptible hosts are widely grown in the risk assessment area. Hence, the burrowing nematode has the potential to cause significant crop yield reductions in the risk assessment area. The total citrus production area in the EU-28 is estimated to be nearly 500 000 ha (2007) and takes place mainly in eight countries around the Mediterranean sea: Spain, Italy, Greece, Portugal, Cyprus, France, Croatia and Malta. The major citrus crops produced in the EU are oranges, mandarins, lemons and grapefruit.

Bananas, as the most important host plants of *R. similis*, are mostly cultivated in the outermost regions of Spain (on the Canary Islands, where around 9 500 ha are planted, of which some 3 000 are in greenhouses), France (Guadeloupe and Martinique, around 8 000 ha; however, these areas are outside the scope of the pest categorisation) and Portugal (Madeira) situated in sub-tropical areas, and only 2 % of the EU production takes place in Cyprus (about 320 ha), Greece (Crete, 63 ha—mainly cultivated in greenhouses—and Laconia) and Portugal (the Azores and the Algarve) (Galán Sauco and Farré Massip, 2005; Tzortzakakis, 2008; Agreste, 2011). The total production of bananas in the EU in 2009 was about 600 000 tonnes (Anonymous, 2012).

Many ornamental plants belonging to the families Araceae (*Anthurium* spp., *Epipremnum* spp., *Philodendron* spp., *Spathifillum* spp. and *Syngonium* spp.) and Marantaceae (*Calathea* spp. and *Maranta* spp.) are also important for the EU region.

Based on inoculating trials, severe damage caused by burrowing nematodes has been reported on maize, soybean and sorghum and moderate damage has been reported on potatoes, tomatoes and aubergines (EPPO, 1997); all these host plants are widely distributed or cultivated throughout EU MSs either outdoors or in greenhouses.

3.4.3.2. Climatic conditions (including protected conditions)

Soil type, moisture (rainfall) and temperature, as well as the presence of suitable host plants and plantation age, are the most important factors affecting the numbers of plant parasitic nematodes (Yeates and Boag, 2004) and this will certainly also apply to *R. similis*. The nematode populations in the field may vary considerably in time and space. In Florida, the highest *R. similis* populations in citrus soil are found during the late summer to early autumn period, when there is an increase in root growth. Likewise, in coconut palms, maximum nematode populations have been detected in October–November in India at a depth of 50–100 cm, and at a favourable mean soil temperature of 25 °C (Griffith and Koshy, 1990).

Experimentally it has been shown that the population of *R. similis* builds up most rapidly in sandy soil, followed by gravelly or loamy soil. There was hardly any build up in clay soils (Gnanapragasam, 1990). Abundance of *R. similis* is influenced by soil porosity. In order to move through the soil, this nematode requires capillaries with water films and a diameter of 30–300 µm, which is larger than the diameter of the nematode's body (Otobe et al., 2004; Duyck et al., 2012). In vertisols, for example, these two conditions rarely occur together. Thus, *R. similis* is unlikely to increase in number in vertisols (Duyck et al., 2012).

With regard to moisture, water-saturated soils were found to be less favourable to *R. similis* than drained and even dry natural soils (Chabrier et al., 2010). In very wet or dry soil, populations of the nematode decline (Gnanapragasam, 1993). This nematode has been detected in soils with 0.5 % moisture, and, under greenhouse conditions, in soil moistures of 75–100 % field capacity (O'Bannon and Tomerlin, 1971).

In addition to soil texture, host plant species and plantation age are important for *R. similis* population levels (Chabrier et al., 2010). Although soil texture seems to play a less important role for *R. similis* damage on bananas, soil texture is a more important factor in citrus species. The disease in citrus species known as spreading decline, which is caused by this nematode, occurs in central Florida. It is aggravated by coarse sandy soil with low organic matter content, but is alleviated by fine-textured soils that are rich in organic matter. In areas where the disease occurs, the soil top layer is 30–60 cm deep and very rich in organic matter, whereas the sub-soil consists of coarse, deep (2–3 m) and well-drained sand with low organic matter content (< 1 %). It is suspected that the top soil contains biological factors that are antagonistic to nematodes, such as soil insects, fungi and bacteria, which are absent in deeper soil layers (O'Bannon and Tomerlin, 1971; Inserra et al., 2005).

The reproductive rate of *R. similis* is dependent on the ambient temperature (Elbadri et al., 2001). Based on experiments on banana plants in growth chambers, the reproduction of different isolates of *R. similis* was found to be highest between 25 and 30 °C (Fallas et al., 1995; Pinochet et al., 1995). Gowen and Quénéhervé (1990) reported that *R. similis* completes its life cycle in 20–25 days at 24–32 °C. On citrus species, *R. similis* completes its life cycle within 18–20 days at 24–27 °C (Tarjan and O'Bannon, 1984). On coconut trees, the entire life cycle is completed in approximately 25 days at 25–28 °C (Griffith and Koshy, 1990). Most populations of *R. similis* reproduce best at intermediate (25 °C) and high (30 °C), rather than lower (15–20 °C), temperatures (Duncan and Moens, 2006). Generally, this nematode does not reproduce at temperatures below 16–17 °C (Pinochet et al., 1995; Sarah et al., 1996) or above 33 °C (Sarah et al., 1996). However, populations exposed to lower temperatures for longer periods could also adapt and reproduce at 15 °C (Elbadri et al., 2001). Populations of *R. similis* introduced into Europe were able to adapt to the colder conditions and thus to reproduce at temperatures too low for most tropical populations (Elbadri et al., 2001; Duncan and Moens, 2006).

Conclusion

In southern Europe, there are a number of citrus-growing areas (Spain, Italy, Greece, Portugal, Cyprus, France, Croatia and Malta) where climatic and cultural conditions are favourable for the establishment and development of *R. similis* in the field. In addition, throughout Europe, there are numerous glasshouses where many ornamental plants (in some areas also bananas) are typically grown at a temperature of 25 °C, thus offering a favourable environment for this nematode. In the EU, *R. similis* is locally established on ornamental plants in glasshouses in Belgium, France, Italy and the Netherlands.

3.4.4. Spread capacity

The burrowing nematode originated from either the Indo-Malayan peninsula or Australasia. From there, it has spread into new areas throughout the world on underground parts of infested planting material, such as rootstocks, corms and tubers, and in accompanying soil (Duncan and Moens, 2006). Although it has a broad host range, *R. similis* is probably most often disseminated to banana plantations owing to frequent exchanges of infected rhizomes, and is now widespread in tropical and sub-tropical areas (O'Bannon, 1977; Elbadri et al., 2001). The introduction of *R. similis* into the New World begun in 1516 (on Española Island), but its main dispersal happened after 1960, when banana cultivars of the Cavendish subgroup (*Musa* AAA), which are resistant to Panama disease (*Fusarium oxysporum* f. sp. *cubense*) but susceptible to the burrowing nematode, have been regularly planted (Marin *et al*., 1998; Volcy, 2011). *R. similis* is also present in glasshouses in some parts of Europe (Elbadri et al., 2001), where it was introduced in the 1960s with ornamental plants, in particular *Anthurium* (EPPO, 2008).

R. similis cannot move actively over very long distances. However, owing to its wide host range and virulent behaviour, the nematode has been reported to move efficiently locally (Duncan and Moens, 2006) and, in citrus groves, *R. similis* has been reported to spread at a rate of 6–60 m per year, with averages of 15 m annually (Suit and DuCharme, 1953; O'Bannon, 1977). Based on the studies conducted in Honduras, the rate of spread of *R. similis* on 'Valery' banana was approximately 2.5 m in one year (according to Wehunt; see O'Bannon, 1977).

Locally, *R. similis* can also be disseminated through soil, water or other organisms (O'Bannon, 1977). Duncan and Moens (2006) reported that this nematode can be dispersed by the movement of soil for construction purposes or on agricultural machinery. *R. similis* can survive in host-free soil for about six months (Inserra et al., 2005; Brooks, 2008; Chabrier et al., 2010). Agricultural machinery is a very important means of nematode spreading within a farmer's fields/plantations, between fields/plantations of one farmer and from farm to farm. It is well known that soil can adhere to machinery and be moved over long distances.

Vectors of the burrowing nematode can also be wild animals that visit one field and move to the next. Soil that contains nematodes that adheres to feet, paws, etc. could be moved to adjacent fields.

Many authors (Faulkner and Bolander, 1970; Burr and Robinson, 2004) consider that these nematodes can mainly be spread by water (Chabrier et al., 2009). *R. similis* has been reported, in Florida and Jamaica, to be spread by water in citrus orchards and banana plantations, respectively (Chabrier et al., 2009). The pest can also be spread by run-off water. The efficiency and the range of this dissemination depend on the nematode's ability to survive in water (Chabrier et al., 2009, 2010). *R. similis* has been reported to survive in water for several weeks. Thus, it is possible that this species can be spread by run-off water not only at the field scale, but also over long distances (Chabrier et al., 2010).

3.5. Elements to assess the potential for consequences in the EU

3.5.1. Potential pest effects

R. similis has been spread through most of the tropical and sub-tropical areas of the world in contaminated planting material such as rootstocks, corms and tubers and is currently one of the world's most important plant nematode pests (Duncan and Moens, 2006). This refers mainly to the banana race of the burrowing nematode, which is both highly invasive and highly polyphagous. The banana race is present in most areas where its host plants are grown, whereas the citrus race is present only in Florida, parts of the Caribbean, Cote d'Ivoire and Guyana (Brooks, 2008). *R. similis* is considered to be among the 10 most damaging plant-parasitic nematodes worldwide (Sasser and Freckman, 1987; Jones et al., 2013).

R. similis has over 365 host plants (EPPO, 2008; Brooks, 2008; Moens and Perry, 2009; CABI, 2014) and is mainly known as a parasite of perennial plants, such as citrus species, bananas, coconuts, peppers and tea (Chabrier et al., 2009). Damage to roots by *R. similis* reduces the uptake of water and nutrients, which leads to yellowing, stunting, a reduction in the number and size of leaves and fruit, a delay in flowering, overall sparse foliage of fruit trees and, finally, a shorter production life of plantations.

In citrus species, *R. similis* is the causal agent of spreading decline, a severe citrus disease, encountered only in the deep sandy soils of central Florida, USA (Inserra et al., 2005; Duncan and Moens, 2006). In the mid-1990s, this disease was responsible for yield losses of 40 to 70 % of oranges and 50 to 80 % of grapefruit (Brooks, 2008). *R. similis* severely damages the fibrous roots of citrus trees causing severe yield reductions of as much as 80 % in fruit production compared with healthy trees (Inserra et al., 2005). The age of the tree, citrus variety, farming practices in the orchards and duration of the nematode infestation have an impact on the reduction of the fruit production of trees damaged by *R. similis* (DuCharme, 1968; Duncan and Cohn, 1990). Because of the great economic importance of citrus production in Florida, millions of dollars have been spent on surveys, research on the biology of the nematode, and management of the disease (Thorne, 1961).

R. similis causes damage to bananas by infecting roots and rhizomes and is recognised as a major nematode pest of bananas worldwide, causing yield losses of up to 30–60 % in many countries (Brooks, 2004). Yield losses of 12.5 tonnes/ha in bananas have been reported as a consequence of *R. similis* infection (O'Bannon, 1977). Economic losses are sometimes difficult to assess because *R. similis* often co-exists with many other nematode species such as root-knot (*Meloidogyne*), lesion

(*Pratylenchus*) or spiral (*Helicotylenchus*) nematodes that can also influence banana yields (Brooks, 2008).

R. similis is a very important pathogen of several indoor ornamental plants such as *Anthurium*, *Calathea* and *Dracaena* (Uchida et al., 2003; Volcy, 2011) and may strongly reduce their commercial production.

The burrowing nematode can also infest many economically important annual crops such as aubergine, bean, beet, broccoli, cabbage, clover, lettuce, lucerne, muskmelon, onion, pepper, pumpkin, radish, rice, rye, sorghum, soybean, strawberry, watermelon and many other crops grown outdoors in the risk assessment area (Table 6). However, *R. similis* is not considered as a major pest of these crops because of its poor long-distance dispersion capacity combined with its relatively poor survival ability in soil (Chabrier et al., 2009).

Citrus spp. are widely grown in a number of areas in southern Europe, where climatic and cultural conditions are favourable for the establishment and development of *R. similis* in the field. Therefore, this nematode has the potential to cause significant crop yield reductions. In addition, *R. similis* may reduce yields in glasshouses throughout the EU, where many ornamental plants (and in some areas also bananas) are grown at a temperature of 25 °C, which is suitable for *R. similis* reproduction and its population build up.

3.5.1.1. Environmental consequences

Consequences of *R. similis* on the environment (except on the production of several economically important host plants such as citrus species, bananas and many ornamental plants) are not expected. Moreover, there is no chemical treatment in use in EU MSs to control this pest, and no indirect consequences are likely to occur. However, indirect effects may be possible if high levels of nematicides were to be allowed for the control of nematodes.

3.5.2. Observed pest impact in the EU

The pest is currently locally established on ornamental plants under protected cultivation in Belgium, France and the Netherlands, but at a low prevalence (Table 4). No EU MS reported impacts of *R. similis* in the questionnaire circulated by EFSA before drafting this opinion.

3.6. Currently applied control methods in the EU

In order to reduce crop losses caused by *R. similis*, a number of management measures—including certification, use of plant-resistant cultivars and adequate agrotechnical, physical and chemical methods—were developed. In Florida, two management systems (“push and treat” and “buffers”) were used for eradication and containment.

The “push and treat” strategy had the following aims: (1) stopping the spread of decline of citrus species, (2) reducing nematode population densities to non-detectable levels, and (3) returning the infested fields to production (Christie, 1959). The method involved bulldozing diseased trees and some additional rows of symptom-free trees, and extracting stumps and roots. All infested material was destroyed. Remaining roots were destroyed by deep ploughing and the soil was treated with high levels of nematicides (dichloropropene, ethylene dibromide and 1,3-dichloropropene) and kept in fallow for six months to two years before resistant rootstocks were planted (Christie, 1959; O’Bannon, 1977; Duncan and Cohn, 1990).

The “buffer” method involved the establishment of 5- to 18-m wide belts separating infested and non-infested areas, which were kept free from host plants. Within belts, citrus roots were killed by the application of high loads of chemicals (Duncan and Cohn, 1990). In Florida between 1954 and 1974, the total cost for this method together with certification was higher than the total cost of lost production (O’Bannon, 1977), but was estimated to have reduced the spread of the disease by more than 90 % (O’Bannon, 1977; Duncan and Cohn, 1990).

3.6.1.1. Certification

An efficient strategy to control plant parasites is their prevention, which can only be achieved by excluding parasites from their hosts. Appropriate certification programmes seem, therefore, to be an effective measure to suppress and also prevent the spread of *R. similis*. To control the spreading decline of citrus species caused by *R. similis*, the nematode certification programme of all nurseries (not just of citrus species) became mandatory in Florida in 1958. This resulted in no further spread of the burrowing nematode, as well as of the other regulated nematodes, such as *Tylenchulus semipenetrans* and *Pratylenchus coffeae*, which were added to the programme later (Lee, 2004). The key elements of this programme were (1) the certification of nurseries to ensure freedom from nematodes, (2) surveys to define infested areas, (3) the removal and destruction (eradication) of trees infected by spreading decline, and (4) a barrier programme (a host-free belt 5- to 18-m wide) to prevent the dissemination of nematodes from infested to healthy trees (Lee, 2004). Since 1994, only the certification of nurseries to ensure freedom from nematodes has been mandatory, and all the other above-mentioned elements became voluntary (Lee, 2004).

3.6.1.2. Host-plant resistance

Host-plant resistance to *R. similis* seems to be a promising management tool that can increase crop yields in the presence of nematode population densities that exceed damage thresholds (Starr et al., 2002). Varieties of many economically important plants that are resistant to *R. similis* have been successfully developed. There are several banana hybrids with resistance to *R. similis* that originate from two widely recognised sources of resistance, such as the AA diploid subgroup Pisang Jari Buaya (PJB) and Yangambi km5 (YK5) (Musa AAA Ibota sub-group) (De Waele and Elsen, 2002). However, their commercial quality is not equivalent to that of standard cultivated varieties (Brooks, 2008). To date, no black pepper varieties that are resistant to *R. similis* have been found. Consequently, favoured cultivars are sometimes grafted onto the rootstocks of *Piper colubrinum*, a wild relative of black pepper which is resistant to this nematode (Brooks, 2008). Citrus cultivars of high quality and yield are also grafted onto resistant rootstocks (Brooks, 2008), although only a limited number (15 out of 1 400) of citrus species, citrus relatives and hybrid rootstocks tested for resistance have been deemed appropriate for release to growers (Tarjan and O'Bannon, 1984; De Waele and Elsen, 2002). The first citrus rootstocks that were resistant to the burrowing nematode were released in 1964 (De Waele and Elsen, 2002).

3.6.1.3. Agrotechnical control methods

R. similis is able to survive for more than six months without the roots of host plants or live rhizome tissue (Whitehead, 1997). It can also survive on volunteer bananas that grow during the fallow period between cropping cycles, and this was found to be a major cause of carry-over of these nematodes to the next crop (Stirling and Pattison, 2008). Crop rotation with non-susceptible plants, such as *Crotalaria*, and some other management practices, including the elimination of banana regrowth and weeds (and cultivation of a nematode-resistant crop for at least one year), affect populations of *R. similis* and reduce them to levels at which at least six nematicide applications can be saved in each crop cycle (Stirling and Pattison, 2008).

Bare fallowing, crop destruction using the herbicide glyphosate to eliminate regrowth from the previous crop, or growing of fully resistant cover crops was found to decrease heavy infestations of soil to trace populations (Whitehead, 1997; Stirling and Pattison, 2008). Flood fallowing may also affect *R. similis* populations dramatically. After three to seven weeks of flooding, *R. similis* populations in the soil were observed to decrease significantly. However, flooding the soil may harm the soil structure and is only feasible on very flat land (Whitehead, 1997). Nevertheless, the lack of suitable land for profitable banana production makes fallowing impractical (Whitehead, 1997).

Many other phytosanitary approaches have also been implemented to control *R. similis*. These include the use of clean propagative material and approved growing media (sterile peat, clean sand, vermiculite, etc.), the use of clean irrigation water, and weed control (Hockland et al., 2006).

3.6.1.4. Physical control methods

In 1954, Birchfield discovered that immersing citrus roots in water at 50 °C for 10 minutes killed all *R. citrophilus* (Whitehead, 1997. After heat treatment, the plants had to be transferred immediately to cold water for 10 minutes to prevent tissue damage (Whitehead, 1997). Hot water treatment of banana rhizomes at 55 °C for 20 minutes has been extensively used in Cuba against *R. similis* (Decker and Dowe, 1977). The method is effective, but requires costly equipment and may damage the rhizomes (EPPO, 1997). Immersing ornamental plants (*Rhapis excelsa*, *Caryota mitis* and four cultivars of *Anthurium*) infested with *R. similis* into hot water at 50 °C for 10–16 minutes has also been reported to be a highly effective method of controlling burrowing nematodes (Arcinas et al., 2004).

3.6.1.5. Chemical control methods

In the past, soil fumigants such as 1,3-dichlorpropene, ethylene-dibromide and 1,2-dibromo-3-chlorpropane were intensively used in citrus and banana orchards to control the burrowing nematode and to increase citrus and banana yields (EPPO, 1997). It has now been recognised that excessive use of fumigants leads to serious environmental and health problems (Duncan and Moens, 2006). Granular non-fumigant nematicides that were reported to be effective against *R. similis* were organophosphates (fenamiphos, fensulphothion, ethoprophos and isazophos) and carbamates (aldicarb, oxamyl and carbofuran) (Whitehead, 1997).

Owing to environmental concerns, loss of efficacy and the EU authorisation Directive 91/414/EEC to restrict or remove pesticides currently used against plant pests and diseases from the market, there is the need to develop effective alternative and complementary management methods.

3.7. Uncertainty

There is low uncertainty about the taxonomic status of *R. similis*, which is recognised as a valid species. Uncertainty exists regarding the lack of available data from official monitoring surveys. Information on soil types suitable for the establishment of *R. similis* (citrus race) is also missing.

CONCLUSIONS

Table 11 summarises the Panel’s conclusions on the key elements addressed in this scientific opinion in consideration of the pest categorisation criteria defined in ISPM 11 and ISPM 21 and of the additional questions formulated in the terms of reference.

Table 11: The Panel’s conclusions on the pest categorisation criteria defined in the International Standards for Phytosanitary Measures (ISPM) No 11 and No 21, and on the additional questions formulated in the terms of reference

Criterion of pest categorisation	Panel’s conclusions on ISPM 11 criteria	Panel’s conclusions on ISPM 21 criteria	Uncertainties
Identity of the pest	*Is the identity of the pest clearly defined? Do clearly discriminative detection methods exist for the pest?* Only *R. similis* is a valid species that can be accurately identified using light microscopy. *R. citrophilus* has been recognised as an invalid species designation and is a junior synonym of *R. similis*. At least two different races of *R. similis* exist and differentiation between the two races (banana and citrus races) is possible by bio-testing		–
Absence/presence of the pest in the risk assessment area	*Is the pest absent from all or a defined part of the risk assessment area?* The pest is absent from the citrus- and banana-field production sites, but is locally established (banana race) on ornamental plants under	*Is the pest present in the risk assessment area?* The pest (banana race) is locally established on ornamental plants under protected cultivation only in Belgium, France and	Lack of available data from official monitoring surveys

Criterion of pest categorisation	Panel's conclusions on ISPM 11 criteria	Panel's conclusions on ISPM 21 criteria	Uncertainties
	protected cultivation only in Belgium, France and Netherlands. It was officially eradicated from Denmark, Portugal (Madeira) and Sweden and was only intercepted in Germany. There are no reports on the presence of *R. similis* under field conditions and there is no evidence for the presence of the citrus race	Netherlands. It was officially eradicated from Denmark, Portugal (Madeira) and Sweden and was only intercepted in Germany. There are no reports on the presence of *R. similis* under field conditions and there is no evidence for the presence of the citrus race	
Regulatory status	*In consideration that the pest under scrutiny is already regulated mention in which annexes of 2000/29/EC and the marketing directives the associated hosts are listed without further analysis. Indicate also whether the hosts and/or commodities for which the pest is regulated in AIIAI or II are comprehensive of the host range.* In the EU, both *R. similis* and *R. citrophilus* are regulated. *R. similis* is regulated as a harmful organism in the EU, listed in Annex II, Part A, Section II of Council Directive 2000/29/EC. *R. citrophilus* is regulated as a harmful organism in the EU, listed in Annex II, Part A, Section I of Council Directive 2000/29/EC. On the basis of these listings, import prohibitions for the entire EU have been formulated for specific commodities (2000/29/EC Annex III) and special requirements have been formulated for specific commodities for the introduction into and movement within all Member States of the EU (2000/29/EC Annex IV, Part A). *Citrus* spp., *Pyrus* spp. and *Fragaria* spp. are potential hosts of *R. similis* which are explicitly mentioned in marketing directives (Council Directive 2008/90/EC). The hosts and commodities for which the pest is regulated are only a fraction of the host range.		
Potential establishment and spread	*Does the risk assessment area have ecological conditions (including climate and those in protected conditions) suitable for the establishment and spread of the pest? Indicate whether the host plants are also grown in areas of the EU where the pest is absent.* *And, where relevant, are host species (or near relatives), alternate hosts and vectors present in the risk assessment area?* Many hosts of *R. similis* are present in the risk assessment area. It is likely that the whole citrus production area of the RA area is suitable for the establishment and spread of *R. similis*. In addition, areas under protected cultivation are also suitable for the establishment and spread of *R. similis*	*Are plants for planting a pathway for introduction and spread of the pest?* Plants for planting are a pathway for introduction and spread of *R. similis*	Information on soil types of the risk assessment area that are suitable for the development of *R. similis* (citrus race) is missing
Potential for consequences in the risk assessment area	*What are the potential consequences in the risk assessment area?* *Provide a summary of impact in terms of yield and quality losses and environmental consequences*	*If applicable, is there indication of impact(s) of the pest as a result of the intended use of the plants for planting?*	Information on soil types of the RA area that is suitable for the

Criterion of pest categorisation	Panel's conclusions on ISPM 11 criteria	Panel's conclusions on ISPM 21 criteria	Uncertainties
	Orange is the second most cultivated fruit crop (after apple) in the RA area. It is likely that *R. similis* can cause citrus spreading decline in the RA area	It is likely that *R. similis* can cause significant losses to citrus production in the RA area	development of *R. similis* (citrus race) is missing. Citrus spreading decline was observed only in certain soil types in Florida
Conclusion on pest categorisation	The pest is absent in the field production sites of the RA area (although it has been reported sporadically on ornamental plants). The climate of the RA area is suitable for establishment and spread, and many hosts are present. The pest can cause significant losses in citrus production	The pest is sporadically present in the RA area on greenhouse ornamental plants in some Member States, can be spread via the movement of plants for planting and can cause significant losses to citrus production in the RA area	Lack of available data from official monitoring surveys
Conclusion on specific ToR questions	*If the pest is already present in the EU, provide a brief summary of* - *the analysis of the present distribution of the organism in comparison with the distribution of the main hosts, and the distribution of hardiness/climate zones, indicating in particular if in the risk assessment area, the pest is absent from areas where host plants are present and where the ecological conditions (including climate and those in protected conditions) are suitable for its establishment* The environmental conditions in southern Europe are favourable for *R. similis* development and reproduction in the field, as most populations of this species reproduce best between 25 and 30 °C *and* - *the analysis of the observed impacts of the organism in the risk assessment area* No EU Member State reported impacts of *R. similis* in the questionnaire circulated by EFSA before drafting this opinion		

PRA, pest risk assessment; EU, European Union; RA, risk assessment.

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ABBREVIATIONS

EC	European Commission
EFSA	European Food Safety Authority
EPPO	European and Mediterranean Plant Protection Organization
EPPO-PQR	European and Mediterranean Plant Protection Organization Plant Quarantine Retrieval System
EU	European Union
ISPM	International Standard for Phytosanitary Measures
MS(s)	Member State(s)
NPPO	National Plant Protection Organization
PRA	pest risk assessment
RA	risk assessment