**EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION**

**ORGANISATION EUROPEENNE ET MEDITERRANEENNE POUR LA PROTECTION DES PLANTES**

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# Report of a Pest Risk Analysis for

# *Meloidogyne graminicola*


Symptoms on rice. Courtesy: Cristiano Bellé, Phytus Institute (BR) – EPPO Global Database (EPPO Code: MELGGC)

This summary is based on an Italian PRA prepared in 2018 (CREA, 2018; Torrini *et al.*, 2020), additional literature searches done by the EPPO Secretariat and subsequent discussions in the EPPO Panel on Phytosanitary Measures. A German express PRA (JKI, 2022) and a Polish express PRA (2019) were also prepared but could not be fully exploited in this report.

The PRA area in the Italian PRA is limited to Italy and the area covered in the German PRA is the EU with a focus on Germany. However, the Panel on Phytosanitary Measures considered that, with few additions, these national PRAs could be used to draft recommendations for the whole EPPO region. Probability of entry, establishment, spread, and potential impact, with associated uncertainties, have been extracted from the PRAs (rated on a three-level scale: low, moderate, high) and, when necessary, adapted by the Panel for the EPPO region. The measures recommended were initially adapted from Reference document 22-27654 *Guidance for expert working groups for PRA and Panels on risk management measures for Meloidogyne species* (later called in this report, the '*Guidance document*') as well as the Commission Implementing Regulation (EU) 2022/1372 for *Meloidogyne graminicola* adopted on 2022-08-05 (EU, 2022).

This PRA report focuses on impact on rice.

| | |
|---|---|
| **Pest:** | *Meloidogyne graminicola* |
| **PRA area:** | Italy (IT PRA) and the European Union (DE PRA), extended to the EPPO region |
| **Assessors:** | Pio Federico Roversi, Giulia Torrini, Leonardo Marianelli - CREA DC, Florence.<br>Dr. Stephan König and Dr. Gritta Schrader – JKI<br>With subsequent discussions in the Panel on Phytosanitary Measures (PPM) |
| **Date:** | December 2018 (IT PRA), May 2022 (DE PRA) and March 2023 (PPM)<br>EPPO Working Party on Phytosanitary Regulations and Council agreed that *Meloidogyne graminicola* should be added to the EPPO A2 List of pests recommended for regulation as quarantine pests in 2023. |

Cite this document as:

EPPO (2023) Report of a pest risk analysis for *Meloidogyne graminicola*. EPPO, Paris. Available at https://gd.eppo.int/taxon/MELGGC/documents

**Based on this PRA report, measures for *Oryza sativae* plants for planting with roots, soil as such, used equipment and machinery, and passengers are recommended. In addition to the measures to be implemented by the exporting countries, importing countries are encouraged that plants for planting with roots, as well as bulbs, tubers, corms and rhizomes of host plants, used in rotation with *Oryza sativa*, should be free from *M. graminicola***

| **STAGE 1: INITIATION** | |
|---|---|
| **Reason for doing PRA**: | The rice root-knot nematode (*Meloidogyne graminicola)* has emerged as a major threat throughout the world and is the most important nematode causing damage on rice (*Oryza sativa*). Until 2016, *M. graminicola* was found only in Asia, parts of the Americas, Madagascar and in South Africa. In July 2016, it was found in Northern Italy in 7 rice fields in the Piedmont region (provinces of Biella and Vercelli). This was the first detection in the EPPO region, and for this reason, the EPPO Secretariat decided to add this nematode to the EPPO Alert List. *Meloidogyne graminicola* was detected again in rice fields in May 2018 in Lombardy region (province of Pavia).<br><br>The measures recommended were initially adapted from Reference document 22-27654 *Guidance for expert working groups for PRA and Panels on risk management measures for Meloidogyne species* (later called in this report, the '*Guidance document*'). |
| **Taxonomic position of pest:** | Nematoda (1NEMAP)<br>Class Chromadorea (1CHROC)<br>Order Rhabditida (1RHABO)<br>Family Meloidogynidae (1MELGF)<br>Genus Meloidogyne (1MELGG) |

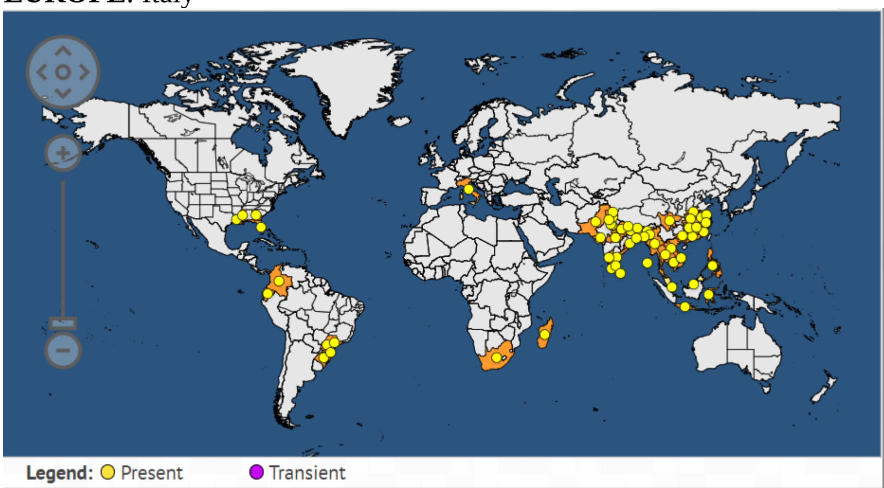
## STAGE 2: PEST RISK ASSESSMENT

### PROBABILITY OF INTRODUCTION

***Entry***

Geographical distribution:
(Source: EPPO Global Database last consulted 2022-09-12, details on distribution are available in Global Database)

**AFRICA**: Madagascar, South Africa
**AMERICA**: Brazil, Colombia, Ecuador, United States of America
**ASIA:** Bangladesh, Cambodia, China, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Vietnam.
**EUROPE**: Italy




EPPO GD (last updated 2023-02-02)

Major host plants:
(See EPPO Global database for references)

The major host of *M. graminicola* is rice.
The nematode can also infest more than 150 plant species belonging to different families (mainly Poaceae but also Asteraceae, Cucurbitaceae, Fabaceae, Solanaceae), including plants of economic importance to the

EPPO region. The list of host plants (and references) is available in the EPPO Global Database:
(https://gd.eppo.int/taxon/MELGGC/hosts)
*Meloidogyne graminicola* was initially found on small barnyard grass (*Echinochloa colonum*) in Louisiana (Golden & Birchfield, 1965). *Meloidogyne graminicola* is frequently found associated with other cereals, as well as dicotyledonous and grass plants, including many weeds that may constitute a major reservoir of nematodes (Rich *et al.*, 2009).
In Italy, *M. graminicola* has been found associated with rice and weeds growing in the vicinity of affected rice plants (*Alisma plantago-aquatica*, *Cyperus difformis*, *Echinochloa crus-galli*, *Heteranthera reniformis*, *Murdannia keisak, Oryza sativa* var. *selvatica, Panicum dichotomiflorum*, *Panicum* spp.).

**In the literature, conflicting information is found on the importance of certain hosts.**

The information presented below relates to the uncertainty on host status for plants which are important crops in the EPPO region and on those which are also used in rotation with rice in the EPPO region (the latter information is important to evaluate potential pathways for the introduction of the pest to the rice cultivation system).

***Host status of important crops other than rice***
Eggplant (*Solanum melongena*) and pepper (*Capsicum*) are mentioned in literature as hosts of *M. graminicola* (for references see EPPO Global Database).
However, Roy (1977) tested the susceptibility of 37 crop plants to *M. graminicola*. *Capsicum frutescens* (chilli pepper) was classified as non-host. Dabur *et al.* (2004) also evaluated the susceptibility of *S. melongena* (eggplant) and noted that this plant did not support the multiplication of *M. graminicola*.

***Host status of plants used in rotation with rice in the EPPO region.***
Information on host susceptibility of the species used in rotation in the EPPO region has been searched. As rice is the main crop affected by the nematode, the intention was to help identifying the likelihood of introduction of *M. graminicola* in the rice cropping system with other hosts. Information on the crops used in rotations with rice in the EPPO region could be gathered from Italy, France, Portugal, Spain, Romania and Russia and is presented below.
Alfalfa (*Medicago sativa*), barley (*Hordeum vulgare*), broccoli (*Brassica oleracea* var. italica), clover (*Trifolium* sp.), lentil (*Lens culinaris*), maize (*Zea mays*), oat (*Avena sativa*), ryegrass (*Lolium multiflorum*), soybean (*Glycine max*), sunflower (*Helianthus annuus*), tall fescue (*Schedonorus arundinaceus*), tomato (*Solanum lycopersicum*), wheat (*Triticum* sp.), winter vetch (*Vicia villosa*), pea (*Pisum sativum*), *Cicer arietinum*, *Phaseolus vulgaris* (Carlin *et al.*, (2004); Delos M (FR), pers. comm., 2023; Gómez de Barreda *et al.*, 2021; Russo & Callegarin, 1997; UniversityAgro, 2021; Soil care, online; M Groza (RO), pers. comm. 2023 ).

A publication from 1997 refers to rotation with soybean (Alionte, 1997) but no more recent information could be found. In Turkey and Portugal continuous growing of rice crops seems to be the practice (Directorate of Trakya Agricultural Research Institute, online; ML Ignacio (PT) pers. comm. 2023).

Many of the studies have been performed based on pot tests not at field level.

Some of the crops used in rotation in the EPPO region, such as barley, maize, oat, soybean, tomato, *Trifolium repens* and wheat, are mentioned in literature as hosts of *M. graminicola*. Information retrieved on some of these hosts is presented below.

*Meloidogyne graminicola* is considered as a growing concern for **barley** in rice growing regions (Vaish *et al*., 2020).
**Maize** was recorded to be infested in regions of India with subtropical climate (Singh *et al.*, 2018) but acted as non-host in a study performed by Soares *et al.* (2022) who investigated the response of different Poaceae crops, soybean and common weeds of rice to biotypes of *M. graminicola* detected in Brazil.
Resistance of **oat** to *M. graminicola* was evaluated by Yao *et al.* (2020) which showed that susceptibility varies between breeding lines.
The nematode has been detected recently on **tomato** in China (Pan *et al*., 2022) and the nematode reproduction factor (RF = final population/initial population) was 5.3. However, Pooja Devi *et al.* (2016) performed inoculation tests on pearl millet (*Cenchrus americanus)*, sorghum (*Sorghum bicolor)*, eggplant, rice and **tomato** as well as three weeds of rice. All plants except **tomato** were found susceptible to all five populations of *M. graminicola* used in the study. Dabur *et al.* (2004) evaluated the susceptibility of tomato and noted that this plant did not support the multiplication of *M. graminicola*.
Rao *et al.* (1984), mention that **soybean** was observed to inhibit the growth of rice root-knot nematode. Soares *et al.* (2022) concluded that *Avena strigosa* (black oat), *Avena sativa* (**oat**), *Urochloa trichopus* (signal grass), *Pennisetum glaucum* (millet), **maize** and **soybean** acted as non-hosts (RF < 1) in both experiments. Aggressiveness depended on the biotypes.
Dabur *et al.* (2004) tested the susceptibility of **wheat** and concluded that it was a '*good host'* of *M. graminicola*. *M. graminicola* is considered as a growing concern for **wheat** in rice growing regions (Vaish *et al*., 2020).
However, the study conducted by Soares *et al.* (2022, see above) showed that **wheat** varieties evaluated served as poor or non-hosts to the nematode.

The EU regulation on *M. graminicola* EU (2022) mentions cultivated host plants of the genus *Brassica* or species *Allium cepa*, *Glycine max*, *Hordeum vulgare*, *Panicum miliaceum*, *Sorghum bicolor*, *Triticum aestivum* and *Zea mays*, intended for the production of bulbs, vegetables or grains for final users other than the use as plants for planting - as possible host plants being allowed in rotation with rice as measure for containment.

*Allium cepa* (onion) is not recorded as being used in rotation with rice in the EPPO region but it should be noted that was shown to support the multiplication of the nematode. It has been a problem when used in rotation with rice as reported in Vietnam (Nguyen *et al.*, 2020).

The following plants used in rotation with rice are not known to be hosts of the nematode:
Lentil (*Lens culinaris*), sunflower (*Helianthus annuus*), tall fescue (*Schedonorus arundinaceus*), winter vetch (*Vicia villosa*), *Cicer arietinum.*
Alfalfa (*Medicago sativa*) is not reported as a host, but *Medicago polyceratia* (weed) is.
Broccoli (*Brassica oleracea* var. italica) is not reported as a host, but other *Brassica* species are.
Other plants are recorded as hosts however, it should be noted that host status depends on the host plant varieties and on the *M. graminicola* biotypes. This is reflected by the conflicting publications regarding wheat and tomato as **important hosts** to support multiplication of the nematode.

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| <u>Which pathway(s) is the pest likely to be introduced on:</u> | The pathway(s) which led to the introduction of *M. graminicola* in Italy is/are not known. Fanelli *et al.* (2022) suggest, based on phylogenetic analysis, that the two Italian outbreaks are related to two different introductions.<br>The following pathways for entry are relevant (by order of importance, pathways not rated individually):<br><br>• Host plants for planting, with roots, with or without soil or growing media attached, and bulbs, tubers, corms and rhizomes of host plants, for planting, with or without soil or growing media.<br>The nematode is associated with the roots of its host plants or with soil (or growing media).<br><br>Rice production in the EPPO region is based on direct seed sowing. Use of transplants to establish a crop only occurs in rare cases in Spain (Kraehmer *et al.*, 2017). In Italy, until the 1960s, about 50% of rice crops were grown from transplants from nurseries. This technique is now completely abandoned and direct sowing is performed (except for trials) (Lazzaris, 2019). It is also the case in France (Mouret, 2007), Russia (Zelenski, 2016) and Turkey (Directorate of Trakya Agricultural Research Institute, online).<br>Transplants are used to establish tomato crops grown in rotation with rice in Spain, only country where tomato is reported to be planted in rotation with rice (Garnica I. pers. com. 2023).<br>Some other host plants may be imported with soil or in pots, such as ornamental plants. However, the transfer requires that ornamental plants are discarded near a rice field which is likely to be a rare event. A list of hosts of *Meloidogyne graminicola* that can be used as ornamental plants is presented in Appendix 1.<br>No bulbs, tubers, corms and rhizomes of host plants for planting are reported to be used in rotation with rice in the EPPO region; this is consequently not considered.<br><br>• Non-host plants for planting with soil or growing media attached.<br>Eggs, second-stage juveniles and males can be found in the soil or growing medium in which infected host plants have been grown.<br>The main risk for non-host plants would result from plants used in rotation with rice (see previous section).<br>Apart from broccoli (used in Spain in rotation with rice) these are sown crops and consequently this pathway presents a very low risk and is not considered further (see analysis of the seed pathway below).<br><br>• Plant parts (not intended for planting) that may have soil attached (such as bulbs, tubers, corms, rhizomes). This includes hosts and non-hosts.<br>Not relevant in relation to the risk for rice (Although mentioned in the EU regulation, *Allium cepa* is not reported to be used in rotation with rice).<br><br>• Soil as such.<br>*(for rationale, see non-host plants for planting with soil or growing media attached)*<br>The import of soil and growing media as such is usually regulated in the EPPO region (e.g. import of soil and growing media as such from third countries other than Switzerland into the EU is prohibited according to Annex VI point 19 and 20 of Commission Implementing Regulation (EU) 2019/2072).<br><br>• Soil attached to equipment and machinery<br>This pathway is linked to soil that can be present on equipment or |

machinery.

- Seeds

*Meloidogyne graminicola* is not associated with seeds, but soil and plant debris may be present in seed lots. However, when reviewing the Guidance document, it was commented that soil attached to seed may be a pathway for cyst nematodes (cysts), but not for root-knot nematodes: soil attached to seeds will dry out too quickly to allow root-knot nematode survival on the surface.

- Passengers

This pathway is linked to soil attached to footwear. It would be mainly the case when persons visiting an infested area do not clean their footwear properly before and after entering rice fields.

- Birds

Waterbirds have been considered as a potential pathway in the Italian PRA for spread between fields. However, when reviewing the Guidance document, it was commented that the risk of spread by water birds is negligible in comparison to heavy winds transporting soil over short to medium or even long distances.
Spread via migratory birds between different regions is considered unlikely due to the same reason as for soil: root-knot nematode survival in dry conditions is very short.

- Water

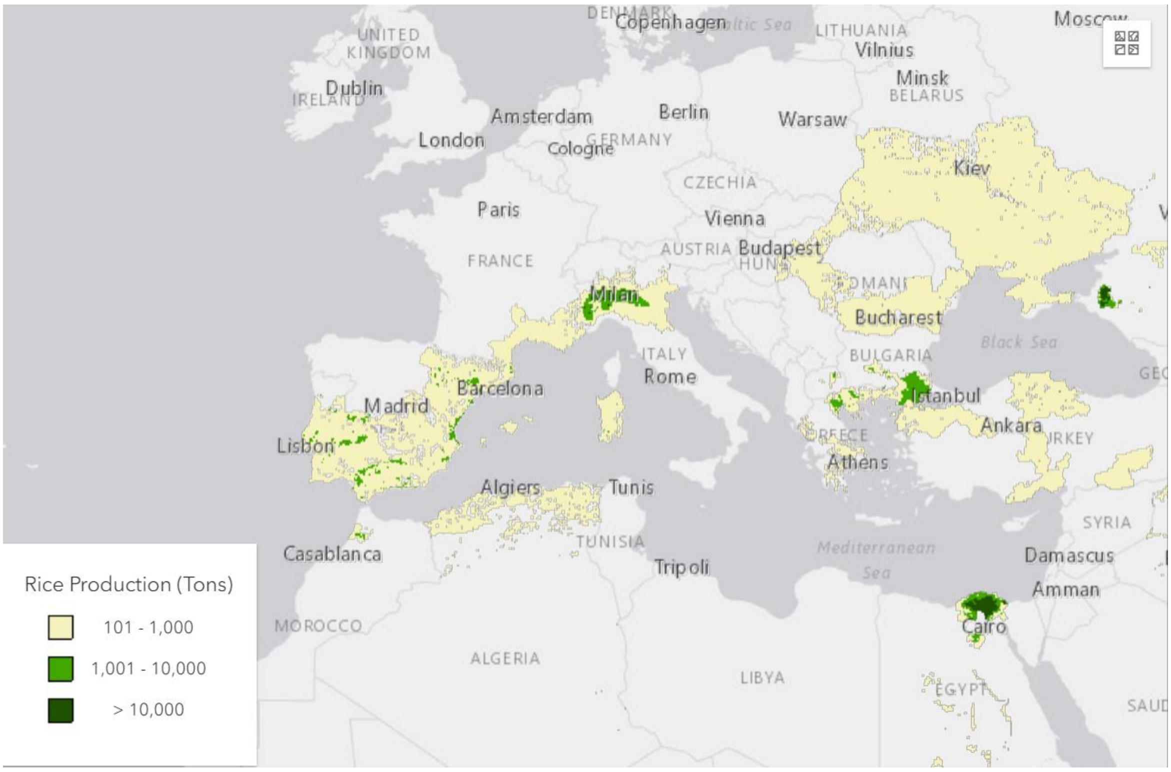
For *M. graminicola* also surface water (as for paddy fields) can be a relevant pathway. Also mentioned in the Italian PRA. *M. graminicola* is adapted to aqueous environment.

***Establishment***

Plants at risk in the PRA area:

The main plant at risk in is rice which is cultivated in the following EPPO countries (source FAO Stat last consulted 2023-03-03)

| Country | Surface (Ha) data from 2021 |
|---|---:|
| Italy | 227040 |
| Russian Federation | 186319 |
| Türkiye | 129475 |
| Kazakhstan | 96634 |
| Spain | 84680 |
| Uzbekistan | 48883 |
| Greece | 34890 |
| Portugal | 29360 |
| Kyrgyzstan | 12404 |
| France | 12290 |
| Bulgaria | 12050 |
| Ukraine | 10100 |
| Morocco | 7555 |
| Romania | 5440 |
| North Macedonia | 3111 |
| Azerbaijan | 3053 |
| Hungary | 2720 |
| Algeria | 167 |

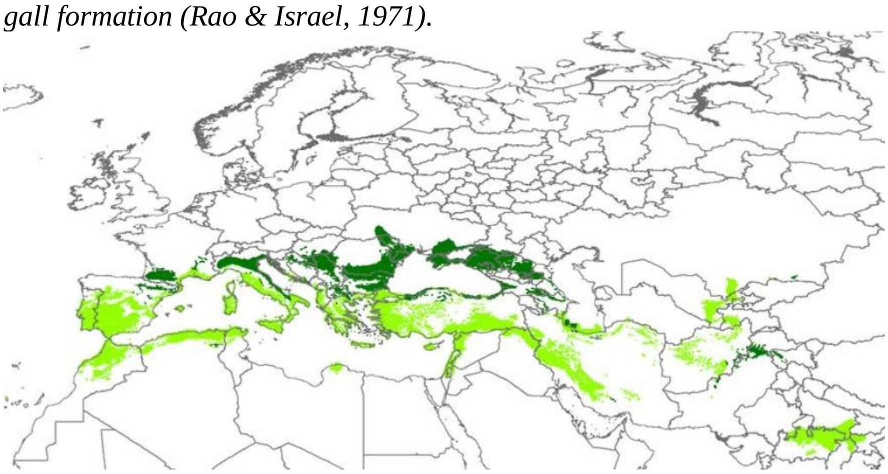



Map of rice production source USDA
https://ipad.fas.usda.gov/cropexplorer/cropview/commodityView.aspx?cropid=0422110

Cultivated crops such as wheat and tomato, are mentioned in literature as hosts of *M. graminicola*, are widely grown in the EPPO region.

Climatic similarity of present distribution with PRA area (or parts thereof):
(full references are provided in the Italian PRA and in Torrini .*et al*, 2020)

This assessment is focused on rice.
In Europe, rice is cultivated between 35° and 45° N. This is the climatic limit for the cultivation of rice, which is originally a tropical species. One crop per year is grown, from April to October.
According to the World Map of Köppen-Geiger climate classification, the rice producing area of Italy are in Cfa [Humid subtropical climates] and Csa [Mediterranean hot summer climates] type.
Climate will probably not be a limiting factor to the establishment of the pest in areas in the EPPO region where rice is grown.
Torrini *et al*., 2020 state that *Temperature is the most important factor, not only for the development of the root-knot nematodes, but also for their distribution, spread and survival (Wallace, 1964). The length of the life cycle is temperature dependent (Trudgill, 1995) and rice root-knot nematode survival is greater at moderate temperatures (Soomro, 1994). Soil temperatures of 23.5°C or less were found to be most favourable for gall formation (Rao & Israel, 1971).*



Köppen-Geiger map showing (see map above Cfa= dark green and Csa=

| | |
|---|---|
| | light green) |
| <u>Characteristics (other than climatic) of the PRA area that would favour establishment:</u> (full references are provided the Italian PRA) | Soil is an important factor for the establishment of root-knot nematodes. Rao & Israel (1972) verified that clay soils were less suitable for this type of nematode infestation; by increasing the sand content, there was an increase in root growth, root-knot nematode development and egg mass production. Sandy or loamy, laterite soils or recent alluvial soils favour the development of the nematode. According to Braasch *et al.* (1996) and Soriano *et al.* (2000), *Meloidogyne* spp. can occur on a wide range of soil types, but their association with crop damage is more readily observed in sandy soils.<br>From the map of Soil Geographical Database of Eurasia, coarse and medium soils are favourable for the establishment of rice root-knot nematodes dominate. (https://esdac.jrc.ec.europa.eu/ESDB_Archive/sgdbe/text-srf-doma3.pdf). See Appendix 2 |
| <u>Which part of the PRA area is the area of potential establishment:</u> | The areas most endangered are areas where rice can be produced. |
| ***Spread*** | **Natural spread** of *M. graminicola* is limited to short distances (in the range of ca. 1 m per year).<br>Water flowing from one infested field to others nearby could spread the pest. In general, nematode spread by water depends on the resistance of the nematode to submersion in water. Survival of the rice root-knot nematode was greater in flooded soils (pot experiment conducted for 0 to 12 weeks flooding) than non-flooded soils (Padgham *et al.*, 2003). It should be noted that Sacchi *et al.* (2021) report that rice field flooding seems to be one of the most efficient techniques to control the size of the *M. graminicola* population in Italy (submersion of infested plots with water at least from spring to the following winter; Torrini *et al.*, 2020).<br>Waterbirds have been considered as a potential pathway for spread in the Italian PRA (see also entry section).<br>**Human assisted spread** is considered to play a more important role at short and long distance e.g. with plants for planting, plant parts, agricultural machinery (tractor wheels, tillage and cultivator equipment, any equipment that have direct soil contact) and soil or growing media as such. Water for irrigation is important for local spread but is considered to have a moderate role for spreading of nematodes in new area. |

**POTENTIAL ECONOMIC CONSEQUENCES**

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| **How much economic impact does the pest have in its present distribution:** | Damage data is mainly reported on rice, limited information is available for other hosts.<br>Despite this nematode being a pest of international importance to rice around the world (Jain *et al.*, 2012), limited information has been reported in the literature on exact yield loss data specifically for *M. graminicola*. For example, no data were found about yield losses or environmental impact in America and Africa, although rice is the main crop produced in Madagascar. Only some (not very recent) information was found in the literature regarding the losses of rice production in Asia, where the rice-wheat cropping system is very important (Arayarungsarit, 1987; Netscher 1993). Netscher (1993) report yield losses that can represent up to 87% of production.<br>Mantelin *et al.* (2022) state that '[crop] *losses in flooded rice fields occur by drowning when infected seedlings fail to elongate above the rising flood water, leaving patches of open water in flooded fields' (Bridge and Page, 1982; Fig. 2). Under simulated upland or intermittently flooded conditions, yield losses caused by* M. graminicola *range from 20% to 80% and 11% to 73%, respectively (Plowright and Bridge, 1990; Soriano et al., 2000). In the* |

*field, these losses may be exacerbated in combination with other biotic or abiotic stresses, such as drought. Mg [M. graminicola] is thus a severe constraint to productivity in rice-growing countries.'*

In Italy, damage has only been reported in rice fields. In Piedmont region, a paddy field only (where *M. graminicola* was found in 2016 for the first time) suffered damage due to the infestation, with around 30-40% losses of the crop production. While in Lombardy, for the season 2018, the losses recorded in the rice fields infested by *M. graminicola* were around 50%.

Mantelin *et al.* (2022) state that *M. graminicola* is likely to be an underestimated pathogen because of the lack of specific above-ground symptoms that can lead growers to wrongly attribute the damage to nutritional and water-associated disorders or to secondary diseases.

**Describe damage to potential hosts in PRA area:** Infection by *M. graminicola* in rice induces the formation of galls, mainly at the root tips with a characteristic hook shape, that strongly impair root development and physiology. The disruption of water and nutrient transport by the alteration of the root vascular system leads to above-ground symptoms, such as stunting, chlorosis and loss of vigour, which ultimately result in poor growth of the crop (Mantelin *et al.*, 2022).
Similar symptoms can be seen on other hosts.
The possibility to use resistant rice varieties was not investigated in the existing PRAs.

**How much economic impact would the pest have in the PRA area:** Damage is expected to be similar to those in Italy.

**CONCLUSIONS OF PEST RISK ASSESSMENT**

**Summarize the major factors that influence the acceptability of the risk from this pest:**

**Estimate the probability of entry:** **Moderate** (pathways seem limited but presence in the EPPO region could lead to entry to new countries via contaminated machineries) with a **high uncertainty**

**Estimate the probability of establishment:** **High** with a **low uncertainty** in areas where rice is grown.

**Estimate the magnitude of spread:** **Moderate** with a **high uncertainty** (evaluation mainly based on human assisted spread (including irrigation). Presence in the EPPO region could lead to spread via contaminated machineries.

**Estimate the potential economic impact:** **High** with a **low uncertainty** for rice.
**Low** with the **high uncertainty** for other crops.

**Degree of uncertainty** The main uncertainty in this evaluation is

- Potential damage to other crops than rice
- Pathways for entry and spread
- Temperature for nematode development.

**OVERALL CONCLUSIONS** *M. graminicola* meets all the criteria to qualify as a quarantine pest. In particular, *M. graminicola* is only present locally but is recognized as an important pest of rice. It could cause damage if it was introduced in other rice producing areas. Risk management measures should be considered.

## STAGE 3: PEST RISK MANAGEMENT

### IDENTIFICATION OF THE PATHWAYS

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| **Pathways studied in the pest risk management** | Host plants for planting, with roots, with or without soil or growing media attached<br>Soil as such<br>Used equipment and machinery<br>Passengers |

### IDENTIFICATION OF POSSIBLE MEASURES

**Possible measures for pathways**

***Measures related to the crop or to places of production:***
Pest free area, pest free place of production, pest free production site

***Measures related to consignments:***
Visual inspection and testing (when symptoms are detected)
Removal of soil
Soil treatment

***Measures upon entry of the consignments:***
Post-entry quarantine (in the framework of bilateral agreement).

### EVALUATION OF THE MEASURES IDENTIFIED IN RELATION TO THE RISKS PRESENTED BY THE PATHWAYS

The pest would be difficult to eradicate or contain if introduced, therefore measures should be taken to prevent its further entry and spread in the PRA area.

| | |
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| **Degree of uncertainty** | Uncertainties in the management part are:<br>Importance of the pathways. |

### IDENTIFICATION OF POSSIBLE MEASURES

| **Pathway** | **Measures identified for the exporting country** |
|---|---|
| *Oryza sativae* plants for planting with roots, with or without soil or growing media[a], | Pest-free area (ISPM 4, ISPM 29) *(see details below)*<br>Or<br>Pest-free place of production / Pest-free production site *(see details below)*<br>Or<br>Consignment freedom based on inspection, <u>and</u> testing of asymptomatic plants after harvest[b]. The test should be indicated on the phytosanitary certificate.<br>*[Remark: The Panel on Phytosanitary Measures considered that this option provides a lower protection than previous options]*. |
| Soil as such | Pest-free area (ISPM 4, ISPM 29) *(see details below)*<br>Or<br>Pest-free place of production / Pest-free production site *(see details below)*<br>Or<br>Treated soil (but this may not be practical for large consignments) |
| Used equipment and machinery | Cleaning of machinery and vehicles, see ISPM 41. |
| Passengers | Public awareness<br>Cleaning of footwear |

[a] *Plants produced in tissue culture are excluded from this pathway, but not plants produced in soilless media (Hallmann et al., 2005)[1].*
[b] *For further guidance on sampling, see ISPM 31* Methodologies for sampling of consignment. *Samples can be either incubated, visually inspected and (in case of symptoms) nematodes extracted, or nematodes directly extracted (PM 7/119 Nematode extraction), and identification performed.*

In addition to the measures to be implemented by the exporting countries, the Working Party encourages NPPOs in EPPO countries to recommend that plants for planting with roots, as well as bulbs, tubers, corms and rhizomes of host plants, used in rotation with *Oryza sativa,* should be free from *M. graminicola* (see measures in the table).

**Pest free area for *M. graminicola***
Although it is considered that a PFA would be difficult to establish in practice and to guarantee, a PFA option can be envisaged when the specific conditions detailed below are fulfilled. The PFA option is considered more difficult to establish and maintain in a country where the *Meloidogyne* species is already reported to be present.

| **Elements to take into account for establishing and maintaining a PFA** | Justification |
|---|---|
| - Specific surveys focusing on fields where rice is/has been grown should be performed, and the country should have (or have access to) appropriate identification capacities.<br>At production sites, inspection should in particular be performed shortly before, or at harvest of recorded host plant (e.g. weeds or hosts used in rotation), targeting particularly susceptible species. Where appropriate testing[a] should be performed, it can be done:<br>- immediately after harvest of a host crop (soil testing), or<br>- before planting a crop (soil testing), or<br>- at the end of the growing period of a host crop (soil testing or testing of host plants with symptoms).<br>*M. graminicola* should not be detected.<br>- Data from general surveillance should also be collected to give additional information on a pest status in the area.<br>- Reports on the specific surveys and general surveillance should be provided, with details on the host crops and type of sites surveyed together with their location in the country. | - Many pathways due to the large host range.<br>- Difficult to effectively survey large areas e.g. to find a limited number of infected fields during a general surveillance program: Defining a PFA is possible with an appropriate inspection procedure, although this will have resource implications.<br>- Under unfavourable climate conditions for establishment, certain *Meloidogyne* species may survive up to 5 years. During this time, *Meloidogyne* species may be moved with plants to another country |
| - Measures should be in place to prevent the introduction of the pest in the PFA:<br>• Plants for planting, plant parts and soil should be pest free (see the table of measures)<br>• Machineries and vehicles entering the PFA should be soil free (see the table of measures),<br>• Implementation of strict hygiene protocols appropriate for *M. graminicola* in places/sites of production producing host plants in the PFA should be encouraged. | |

[a] *Remark: soil testing may be difficult and very demanding.*

**Pest free place of production/pest free production site**
***Pest free place of production***
The choice between a PFPP and a PFPS is a decision to be taken by the NPPO based on the operational capacities of the producers and biological elements. The Panel on Diagnostic in Nematology considered that a PFPS was easier to establish and maintain for this pest than establishing and maintaining a PFPP.

***Pest free production site***
Testing should be a basis for the establishment of a PFPS. However, testing should not be a standalone measure for the establishment and maintenance of a PFPS (see table below). The measures presented in the table below should be combined to guarantee a PFPS:

[1] Hallmann J, Hänisch D, Braunsmann J & Klenner M (2005) Plant-parasitic nematodes in soil-less culture systems. Nematology 7, 1-4. Available from https://upload.eppo.int/download/700ofc543bfef

| **Elements to take into account for establishing and maintaining a PFPS** | Justification |
|---|---|
| A 3-year cropping history for the production site should be made available, **and** | 3-year is a good indication of the dynamic of *Meloidogyne* populations. |
| When host plants have been produced in one of the three preceding years, testing[a] should be performed:<br>- shortly before harvest of the last previous host crop (testing of host plants with symptoms), or<br>- immediately after harvest of the last previous host crop (soil testing), or<br>- before planting the crop (soil testing)[b], or<br>- at the end of the growing period of the host crop (soil testing or testing of host plants with symptoms)<br>The production site should be found free from *M. graminicola.*<br>**And** | Risk of contamination with soil. When soil testing is possible, it has the advantage of indicating the pest status of the site before production rather than at harvest. However, the initial soil testing of a PFPS is very demanding. The initial soil testing is not necessary when testing has been performed immediately after harvest of the previous host crop. Alternatively, testing can be done at the end of the growing period of the crop. |
| Inspection at the production site should be performed in particular shortly before or at harvest of recorded host plants of *M. graminicola*, targeting particularly susceptible species, and the production site should not be found infected by the pest, **and** | The level of *Meloidogyne* species would be higher at the end of a host growing period. |
| Pest-free plants for planting, soil, machinery and vehicles should be used (See conditions as specified in the table of measures), **and** | |
| Weed and volunteer hosts in the production site should be controlled, **and** | *M. graminicola* survives in weeds and volunteers. |
| Host plants (including weeds) in the immediate vicinity (few meters) should have been inspected and found free from *M. graminicola*, **and** | |
| Implementation of strict hygiene protocols appropriate for *M. graminicola.* in places/sites of production should be encouraged, **and** | |
| Where appropriate, measures to prevent infestation by irrigation water should be implemented. | |

[a] *Remark: soil testing may be difficult and very demanding.*

[b] *This testing option does not provide the same level of protection but is considered sufficient when used in combination with the other measures.*

One means of implementing these measures could be to grow the commodities in a production site under physical isolation according to Standard PM 5/8.

Eradication and containment measures are detailed in Torrini *et al.* 2020.

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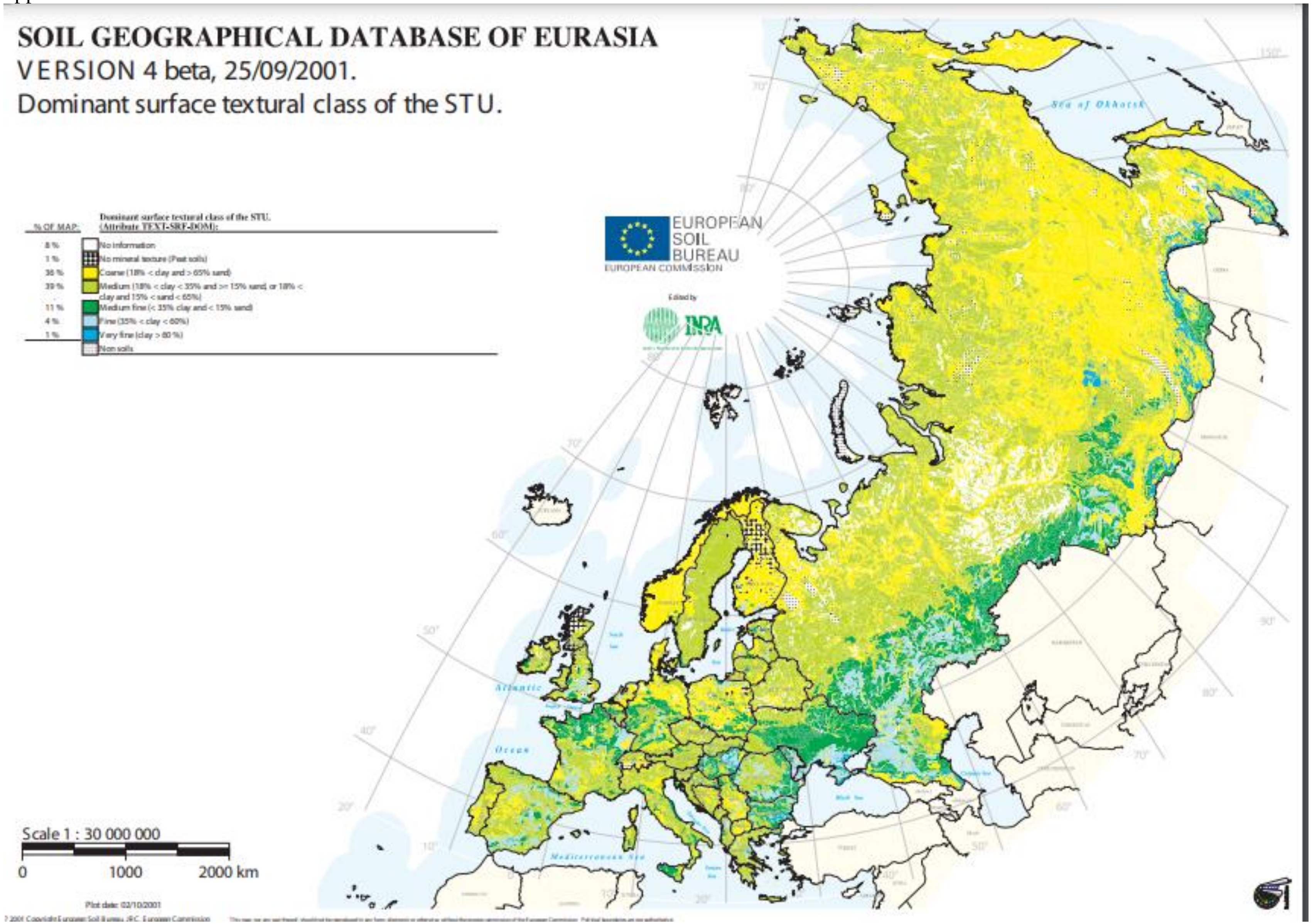
Appendix 1

List of hosts of *Meloidogyne graminicola* that can be used as ornamental plants
(*note that some of these hosts may only be traded as seeds but this analysis was not made*).

| **Species** | **Family** | **Presence EPPO region** | **Reference** |
|---|---|---|---|
| *Alisma plantago* (Common Water- plantain) | Alismataceae | Yes | Rusinque *et al*., 2021 |
| *Alternanthera sessilis* (Sessile joyweed) | Amaranthaceae | Yes | Rusinque *et al*., 2021 |
| *Bothriochloa bladhii* | Poaceae | Yes | Rusinque *et al*., 2021 |
| *Centella asiatica* (Spadeleaf) | Apiaceae | Yes | Rusinque *et al*., 2021 |
| *Coriandrum sativum* (Cilantro) | Apiaceae | Yes | Rusinque *et al*., 2021 |
| *Cyperus rotundus* (Purple nutsedge) | Cyperaceae | Yes | Bellé *et al*., 2019 ; de Lourdes Mendes *et al*., 2020 ; Rusinque *et al*., 2021 |
| *Hydrilla* spp. | Hydrocharitaceae | Yes | Rusinque *et al*., 2021 |
| *Impatiens balsamina* (Garden balsam) | Balsaminaceae | Yes | Rusinque *et al*., 2021 |
| *Imperata cylindrica* (Silver spikegrass) | Poaceae | Yes | Rusinque *et al*., 2021 |
| *Ludwigia adscendens* (Floating water primrose) | Onagraceae | No | Rusinque *et al*., 2021 |
| *Murdannia keisak* (Marsh dewflower) | Commelinaeae | Yes | Rusinque *et al*., 2021 |
| *Musa* (Banana) | Musaceae | Yes | Rusinque *et al*., 2021 |
| *Musa acuminate* (Dwarf banana) | Musaceae | Yes | Zhou *et al*., 2015; Rusinque *et al*., 2021 |
| *Panicum* [2] | Poaceae | Yes | ? |
| *Pennisetum pedicellatum* (Deenanathgrass) | Poaceae | Yes | Rusinque *et al*., 2021 |
| *Petunia* sp. | Solanaceae | Yes | Rusinque *et al*., 2021 |
| *Portulaca oleracea* (Common purslane) | Portulacaceae | Yes | Rusinque *et al*., 2021 |
| *Ranunculus* (Buttercup) | Ranunculaceae | Yes | Rusinque *et al*., 2021 |
| *Rungia parviflora* | Acanthaceae | Yes | Rusinque *et al*., 2021 |
| *Setaria italica* (Foxtail millet) | Poaceae | Yes | Rusinque *et al*., 2021 |
| *Solanum nigrum* (Black nightshade) | Solanaceae | Yes | Rusinque *et al*., 2021 |
| *Solanum sisymbriifolium* (Dense- thorned bitterapple) | Solanaceae | Yes | Rusinque *et al*., 2021 |
| *Sphaeranthus* sp. | Asteraceae | Yes | Rusinque *et al*., 2021 |

[2] *Panicum miliaceum* is cited in GD but is not an ornamental plant. Other *Panicum* in GD are wild/weeds)

Appendix 2



SOIL GEOGRAPHICAL DATABASE OF EURASIA
VERSION 4 beta, 25/09/2001.
Dominant surface textural class of the STU.
% OF MAP:
Dominant surface textural class of the STU.
(Attribute TEXT-SRF-DOM):
8 % No information
1 % No mineral texture (Peat soils)
36 % Coarse (18% < clay and > 65% sand)
39 % Medium (18% < clay < 35% and >= 15% sand, or 18% < clay and 15% < sand < 65%)
11 % Medium fine (< 35% clay and < 15% sand)
4 % Fine (35% < clay < 60%)
1 % Very fine (clay > 60 %)
Non soils
EUROPEAN SOIL BUREAU
EUROPEAN COMMISSION
Edited by
INRA
Sea of Okhotsk
Atlantic
Ocean
Mediterranean Sea
Black Sea
Scale 1 : 30 000 000
0
1000
2000 km
Plot date: 02/10/2001