Pest risk analysis

Meloidogyne graminicola Golden & Birchfield, 1965

December 2018

Summary of the Express Pest Risk Analysis for *Meloidogyne graminicola*
PRA area: ***Italy***
Describe the endangered area: the PRA region. Climatic conditions will not be a limiting factor for establishment. *M. graminicola* may establish and cause damage wherever there are hosts.
Main conclusions *Overall assessment of risk: Meloidogyne graminicola* is already established in the PRA area but only in rice fields. This pest has been found associated with rice plants and some weed plants. Internationally, its spread is more likely to occur through the movement of infected plants for planting and soil or growing medium from Asia. The likelihood of entry with machinery contaminated with infested soil was considered as low with a moderate uncertainty; and with non-host plant parts that may have growing medium attached (such as roots, tubers, bulbs), for consumption or processing, and with travellers as low with a low to moderate uncertainty. Inside the PRA area, the natural spread of this pest is limited. Spread will mostly occur through human assisted pathways, with soil or growing media, on its own or carried on machinery or tools, with plants for planting. In paddy fields, passive transport may also be facilitated by movements of water, wild animals and waterbirds. Rice root-knot nematode is a pest of international importance to rice around the world and it is one of the great concerns for yield loss due to nematode infestation in rice and wheat crops under rice–wheat cropping system. This nematode infests many plant species belonging to different families (mainly Poaceae but also Asteraceae, Cucurbitaceae, Fabaceae, Solanaceae) that include plants of economic importance to the PRA area, but also to EPPO region. The large host range of *M. graminicola* and its ability to survive for long periods in environments with low oxygen render its control very difficult. For these reasons, adequate phytosanitary measures are important. *Phytosanitary Measures to reduce the probability of entry:* The possible pathways considered in this PRA are plants for planting, soil, seeds, waterbirds, soil attached to machinery or tools and travellers coming from infested areas

Phytosanitary risk for the *endangered area* (*Individual ratings for likelihood of entry and establishment, and for magnitude of spread and impact are provided in the document*)	**High** ☒	Moderate ☐	Low ☐
Level of uncertainty of assessment (see Q 17 for the justification of the rating. Individual ratings of uncertainty of entry, establishment, spread and impact are provided in the document)	High ☐	**Moderate** ☒	Low ☐

Other recommendations:

- ***Surveys are recommended to confirm the pest status***

Pest Risk Analysis:

Meloidogyne graminicola Golden & Birchfield, 1965

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Date: December 2018

Stage 1. Initiation

Reason for performing the PRA: Rice root-knot nematode (*Meloidogyne graminicola)* has emerged as a major threat throughout the world and, among nematode species reported in association with rice, it is the most important rice harmful organism. Until recently, *M. graminicola* was present only in Asia, parts of the Americas and in South Africa. In July 2016, it was found in Northern Italy; particularly in 7 rice fields in the Piedmont region (provinces of Biella and Vercelli). This is the first detection in the EPPO region, and for this reason, the EPPO Secretariat decided to add this nematode to the EPPO Alert List. Afterwards, *M. graminicola* was detected also in Lombardy region (province of Pavia) in May 2018 in the area particularly suitable for the rice production.

PRA area: The PRA area is Italy

Stage 2. Pest risk assessment

1. Taxonomy: Domain: Eukaryota

Kingdom: Metazoa

Phylum: Nematoda

Family: Meloidogynidae

Genus: *Meloidogyne*

Species: *graminicola*

Common name: rice root knot nematode

2. Pest overview

2.1 Life cycle

Meloidogyne graminicola *is a root-knot nematode obligate endo-parasite. As with other* Meloidogyne *spp., it has eggs, four juvenile stages and adults. Nematode develops into the egg, where it moults from the first to the second juvenile stage (J2) which then hatches from the egg under favourable environmental conditions, i.e., temperature 20-35°C and moisture. The J2 (L= 415-484 µm) is the infective stage, because it finds the root, enters the meristematic zone and starts feeding. Due to continuous feeding, J2 induces formation of syncytium and gall as typical of root-knot nematodes. The body size increases during 3-4 days after infection and moults into J3 (spiketail stage), J4 and adult male or female stages (Gaur, 2003). Females develop within the roots and eggs are mainly laid in the cortex. The juveniles can remain in the maternal gall or migrate intercellularly through the paerenchyma tissue of the cortex to new feeding sites within the same root (Mulk, 1976; Bridge and Page 1982). This behaviour enables the* M. graminicola *under flooded conditions to multiply within the host tissues even when roots are submerged in water.*

The J3 and J4 do not have functional stylet, hence do not feed and are enclosed in a cuticular sheath from the preceding J2 stage. The adult males can be seen 13-15 days after inoculation and freshly laid eggs can be seen 3-4 days thereafter. Males are not infective, they are vermiform and measure 1,020-1,428µm, while females appear to be pear-shaped to spheroid with small neck (Mulk, 1976). Females of M. graminicola *remain within the galled roots and eggs are deposited in egg masses inside the root cortex. Up to 50 egg-laying females can be found in a single gall, indicating that infection can be extremely high (Bridge* et al. *2005).*

Meloidogyne graminicola *is a facultative meiotic parthenogenetic species in which amphimixis can occur at a low frequency (approximately 0.5%) (Triantaphyllou, 1969). Oogenesis and spermatogenesis* *studies have revealed that the haploid chromosome number (n = 18) is determined during the first and second maturation divisions without any variation in number (Triantaphyllou, 1969). It is assumed that, when males are present and in contact with females, classical amphimixis happens, whereas, in their absence, parthenogenesis takes over.*

The life cycle duration of M. graminicola *varies considerably in different environments, ranging from a very short cycle of only 15 days at 27-37°C (Jaiswal and Singh, 2010) to a rather longlife cycle of up to 51 days in some regions in India (Rao and Israel, 1979). In Bangladesh,* M. graminicola *completes its life cycle within 19 days at 22–29°C (Bridge* and *Page 1982), while USA isolates complete it within 25–27 days at 26°C (Yik and Birchfield, 1979). Singh* et al. *(2006) reported that* M. graminicola *required 15-20 days to complete its life cycle in rice during different months in eastern Uttar Pradesh condition, where temperature usually ranges between 22-40º C.*

Meloidogyne graminicola*, as all* Meloidogyne*, is dependent on external sources of heat and water for its development (Wallace, 1966; Wong and Mai, 1973; Ferris* et al.*, 1978). Temperature is known to influence nematode activities such as hatching, migration, penetration, development and reproduction (Wallace, 1964). Water regime is also an important environmental factor that influences reproduction and population dynamics of* M. graminicola *(Tandingan* et al.*, 1996). Second stage juveniles cannot invade rice in flooded conditions but quickly invade it when infested soils are drained. Soomro (1989) reported that second stage juveniles of* M. graminicola *could survive and remain viable in soil without a host plant for up to 5 months at temperatures up to 26°C. Survival of the rice root-knot nematode was greater at lower temperatures (Soomro, 1994) and in flooded soils (Padgham* et al.*, 2003). Rao and Israel (1972a) reported maximum egg hatching of* M. graminicola *in water at 25°C and 30°C. At 15°C and 35°C, hatching was reduced and at 20°C it was slightly less than at 25°C.*

2.2 Host plants

The main economically important host of M. graminicola *is rice (*Oryza sativa*) but this nematode has a wide host range (Ou, 1972) that includes many of the common weeds of rice fields and can also be damaging to agricultural crops that are grown in rotation with rice, onion, cabbage and tomato. It was initially found on barnyard grass (*Echinochloa colonum*) in Louisiana (Golden and Birchfield, 1965).* Meloidogyne graminicola *is frequently found associated with other cereals, as well as dicotyledonous and grassplants, including many weeds that may constitute a major reservoir of nematodes (Rich* et al.*, 2009). Finally, some cultivated crops such as tomato, eggplant, pepper, soybean are mentioned in literature as hosts of* M. graminicola.

In Italy, M. graminicola *has been found associated with rice and weeds growing in the vicinity of affected rice plants (*Alisma plantago, Cyperus difformis, Echinocloa crus-galli, Heteranthera reniformis, Murdannia keisak, Oryza sativa *var.* selvatica, Panicum dichotomiflorum, Panicum *spp.).*

2.3 Symptoms

The second stage juveniles cause disruption and hypertrophy of cortical cells due to their migration, movement and salivary secretions. Hyperplasia of proto-phloem and abnormal xylem proliferation cause swelling of stele at the site of nematode establishment (Jene and Rao, 1973). As in other root-knot nematodes, the symptoms due to the infestation of M. graminicola *are manifested as characteristic hook-shaped galls of different shapes and sizes, mainly formed at the root tips, leading to stunting and chlorosis of the rice plants in patches within a nursery or a main field, and consequently decreasing the crop yield. The leaf size is reduced, tillering is poor and earhead emergence is delayed. In case of heavy infestation, no earheads may be produced.*

The level of symptom expression differs with time of infestation, age of plants and load of inoculum (McClure, 1977). In upland and lowland rice fields infested by M. graminicola*, when plants are in their first stages of vegetative development (early summer), patches of plants showing poor growth, loss of vigour, stunting, chlorosis with heavily affected root systems can be observed. In late summer and autumn, the above-ground symptoms may regress after flooding and fertilizing, because patches are colonised by the vegetation of growing and tillering plants. At this stage rice fields appear more uniform but infested plants show poor caryopsis production and empty spikelets. These symptoms are more evident in drained fields than in flooded fields.*

Upland and lowland rice fields in North Italy, infected by M. graminicola*, showed patches in which plants were showing poor growth and stunting, chlorosis and heavily affected root systems. Diseased roots showed swelling and galls of different shape and size. Severe infestation and large galls were also observed on weeds on which the symptoms of the above ground part of the plants were like those described on rice (Fanelli* et al.*, 2017).*

The crop loss depends on nematode population density, rice cultivation system (flooded or dry), environmental conditions, and soil structure. It is estimated that M. graminicola *can decrease rice yield by 20 to 80% in upland and by 11% to 73% in intermittently flooded conditions (Plowright and Bridge, 1990; Soriano* et al.*, 2000). In the field, these losses may be aggravated in combination with other biotic or abiotic stresses, such as drought.*

2.4 Detection and identification

Sampling and surveys
Soil and root samples must be collected and analysed by a nematology specialist. Species determination of M. graminicola *is complex and usually based on the symptoms (hook-like galls produced on the rice roots). Assessing the severity of root damage by the amount of galling (root-knot index) is a practical and speedy method but can be difficult with rice.*
Nematodes should be obtained from plant tissues or soil by suitable extraction techniques (according to EPPO Standard PM 7/119 (1) Nematode extraction). Identification to specie level is based on combination of morphological/morphometric characters and biochemical or molecular methods. Accurate identification of nematodes is important and is crucial for understanding the host-parasite relationships and implementing appropriate management options (Pokharel et al.*, 2007).*

Morphological identification
For a reliable identification of Meloidogyne *spp., females and juveniles are required, and males can also be used if present. A morphological description is given in Mulk (1976). Jepson (1987) provides a procedure for the determination of 51* Meloidogyne *species, included* M. graminicola.

Molecular identification
The application of molecular methods has been used with success to identify M. graminicola*; in particular sequences of nuclear ribosomal (rDNA) and mitochondrial DNA (mtDNA) have been largely used (Pokharel* et al.*, 2007, 2010; McClure* et al.*, 2012; Htayetal, 2016). Recently, two molecular methods have been developed: the first used a diagnostic SCAR marker (Bellafiore* et al.*, 2015) for the rapid and reproducible identification of* M. graminicola *and the second one used real-time PCR primers for the quantification of this nematode in soil (Katsuta* et al.*, 2016).*

M. graminicola *formed a well separated cluster from the other* Meloidogyne *species resulting phylogenetically related to* Meloidogyne naasi. *Both species, in fact, possess similar morphological traits and infect rice; however they can be morphologically easily distinguished by the pattern of female perineal region (with a distinct fold over the anus and large phasmids in* M. naasi*, both absent in* M. graminicola*), by the position of excretory pore in female (ca. at level of stylet knobs vs more than one stylet length posterior to stylet knobs in* M. graminicola*) and by the tail terminus shape of J2, tapered and sharply pointed in* M. naasi *vs rounded and often clavate in* M. graminicola *(Fanelli* et al.*, 2017).*

3. Is the pest a vector?	**Yes**	☐	**No**	*X*
4. Is a vector needed for pest entry or spread?	**Yes**	☐	**No**	*X*

5. Regulatory status of the pest
Meloidogyne graminicola *was detected in July 2016 for the first time in the EPPO region in several rice fields of Northern Italy and the EPPO Secretariat decided to add this nematode to the EPPO Alert List in 2017. Since 1995* M. graminicola *was added in Brazil in A1 list.*
In Italy, the Ministry of Agricultural, Food and Forestry Policies issued a Ministerial Decree on 6 July 2017 "Misure d'emergenza per impedire la diffusione di Meloidogyne graminicola *Golden & Birchfield nel territorio della Repubblica italiana".*
Moreover, Meloidogyne *species were regulated non-quarantine pest (2003) in Bahrain (Asia) and since 2007 they were added in Turkey in A2 list.*

6. Distribution

Table 1. *Distribution of* Meloidogyne graminicola *in the world*

Continent	***Distribution***	***Pest status in the different countries where it occurs***	***Reference***
Africa	*- Madagascar* *- South Africa*	*Present*	*Chapuis* et al., *2016;* *Kleynhan, 1991*
America	<u>*North America*</u> *- USA (Georgia, Louisiana, Mississipi)*	*Present*	*Golden and Birchfield, 1965;* *Yik and Birchfield, 1979;* *Windham and Golden, 1990*
	<u>*South America*</u> *- Brazil (Sao Paulo)* *- Colombia* *- Ecuador*	*Present*	*Monteiro and Ferraz, 1988;* *Bastidas and Montealegre, 1994* *Triviño* et al., *2016*
Asia	*- Bangladesh* *- China* *(Fujian, Hainan, Hubei, Hunan, Zhejlang)* *- India (Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bihar, Delhi, Gujarat, Haryana, Himachal Pradesh, Indian Punjab, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Manipur, Odisha, Sikki, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal)* *- Indonesia* *- Laos* *- Malaysia* *- Myanmar* *- Nepal* *- Pakistan* *- Philippines* *- Singapore* *- Sri Lanka* *- Thailand* *- Vietnam*	*Present*	*Page* et al., *1979;* *Zhao* et al., *2001; Zhou, 2015; Wang* et al., *2017; Song* et al., *2017; Tian* et al., *2017* *Rao* et al., *1970; Bajaj and Dabur, 2000; CABI/EPPO, 2001; Dabur and Jain, 2004; Naved and Gaur, 2004; Anitha and Rajendran, 2005; Sheela* et al., *2005; Mohilal* et al.,*2010; Prasad* et al., *2006; Baqri and Ahmad, 2000; Shingh* et al., *2007; Pankaj* et al., *2011; Vaish* et al., *2012; EPPO,2014; Salalia* et al., *2017* *Harish* et al., *2015;* *Netscher and Erlan, 1993;* *Manser, 1968, 1971;* *Zainal-Abidin* et al., *1994;* *Myint, 1981;* *Sharma* et al., *2001;* *Munir and Bridge, 2003;* *Madamba* et al., *1981;* *AVA, 2001;* *Nugaliyadde* et al., *2001;* *Buangsuwon* et al., *1971;* *Kinh, 1982*
Europe	*- Italy (Piedmont and Lombardy)*	*Present*	*EPPO, 2016; EPPO 2018*
Oceania	-	*Not Present*	

<u>Comments on distribution.</u> *The rice root-knot nematode,* M. graminicola *was first reported by Golden and Birchfield (1965) in the roots of barnyard grass* Echinochloa colonum *L. growing in a field at Baton*

Rouge, Lousiana, USA. It is widely distributed in the countries where rice is produced and in particulary in South and Southeast Asia but also in South Africa, United States, Colombia, and Brazil (Dutta et al.*, 2012). In July 2016,* M. graminicola *was detected for the first time in Northern Italy, in 7 rice fields in Piedmont region, in the municipality of Buronzo (province of Vercelli), and in two other localities, Mottalciata and Gifflenga (province of Biella). The infested area was estimated at approximately 20 ha. At the end of 2017* M. graminicola *was detected in 48 rice field (65 ha); and in 2018 the infested area was approximately 90 ha.*

In May 2018 M. graminicola *was found in Lombardy in the municipality of Garlasco (province of Pavia), area particularly suitable for the rice production. The infestation was detected in three not contiguous fields (total 11 ha). During the delimiting survey activities 4 new infested paddy fields were found, which amount to 26 ha. One of the infested fields is in Dorno municipality, 5 km far to the first detection. The total infested area in Lombardy is estimated at approximately 37 ha.*

7. Host plants and their distribution in the PRA area

Table 2. *Host plants of* Meloidogyne graminicola

Host Scientific name (common name)	**Family**	**Host Presence in PRA area**	***Reference***
Abelmoschus esculentus (Okra)	Malvaceae	No	EPPO, 2016
Ageratum conyzoides (Billy goat weed)	Asteraceae	Yes	Khan *et al*., 2004
Agropyron repens (Quackgrass)	Poaceae	No	Khan *et al*., 2004
Alisma plantago (Common Water-plantain)	Alismataceae	Yes	EPPO, 2016
Allium cepa (Onion)	Liliaceae	Yes	Gregon *et al*., 2002
Allium fistulosum (Welsh onion)	Liliaceae	No	EPPO, 2016
Alopecurus (Foxtails)	Poaceae	Yes	MacGowan and Langdon, 1989 Dutta *et al*., 2012
Alopecurus carolinianus (Carolina foxtail)	Poaceae	No	EPPO, 2016
Alternanthera sessilis (Sessile joyweed)	Amaranthaceae	No	Khan *et al*., 2004
Amaranthus spinosus (Spiny amaranth)	Amaranthaceae	Yes	Sperandio and Amaral, 1994; Usha *et al*., 2005
Amaranthus viridis (Slender amaranth)	Amaranthaceae	Yes	Roy, 1977; Usha *et al*., 2005
Ammannia pentandra	Lythraceae	No	Usha *et al*., 2005
Andropogon sp. (Beardgrass)	Poaceae	No	Rao *et al*., 1970
Avena sativa (Oat)	Poaceae	Yes	Birchfield, 1964
Beta vulgaris (Beet)	Amaranthaceae	Yes	Usha *et al*., 2005
Bonnaya brachiata (Hairy Slitwort)	Linderniaceae	No	Roy, 1977; Usha *et al*., 2005
Blumea sp.	Asteraceae	No	Rao *et al*., 1970
Borreria articularis (Jungle	Rubiaceae	No	EPPO, 2016

Host Scientific name (common name)	Family	Host Presence in PRA area	*Reference*
bagracote)			
Bothriochloa intermedia	Poaceae	No	Khan *et al*., 2004
Brachiaria mutica (Buffalo grass)	Poaceae	No	EPPO, 2016
Brachiaria ramosa (Browntop millet)	Poaceae	No	Khan *et al*., 2004
Brassica juncea (Brown mustard)	Brassicaceae	Yes	Bridge *et al*., 2005
Brassica oleracea (Cabbage)	Brassicaceae	Yes	Bridge *et al*., 2005
Brassica sp.	Brassicaceae	Yes	Bridge *et al*., 2005
Brassica oleracea var. botrytis (Cauliflower)	Brassicaceae	Yes	EPPO, 2016
Capsicum annuum (Pepper)	Solanaceae	Yes	Usha *et al*., 2005
Capsicum frutescens (Chilli)	Solanaceae	No	Rao *et al*., 1970
Catharanthus roseus (Madagascar periwinkle)	Apocynaceae	No	Bridge *et al*., 2005; Jain *et al*., 2014
Centella asiatica (Spadeleaf)	Apiaceae	Yes	EPPO, 2016
Chamaesyce hirta (Asthma herb)	Euphorbiaceae	No	EPPO, 2016
Colocasia esculenta (Taro)	Araceae	Yes	Bridge *et al*., 2005; EPPO, 2016; Usha *et al*., 2005
Commelina bengalensis (Benghal dayflower)	Commelinaceae	No	Bridge *et al*., 2005
Corchorus capsularis (White jute)	Malvaceae	No	Bridge *et al*., 2005
Coriandrum sativum (Cilantro)	Apiaceae	Yes	Usha *et al*., 2005
Courtoisina cyperoides		No	EPPO, 2016
Cucumis sativus (Cucumber)	Cucurbitaceae	Yes	Bridge *et al*., 2005
Cymbopogon citratus (Lemon grass)	Poaceae	Yes	EPPO, 2016
Cyanotis cucullata	Commelinaceae	No	Ravindra *et al*., 2017
Cynodon dactylon (Bermuda grass)	Poaceae	Yes	Usha *et al*., 2005
Cyperus brevifolius (Kyllinga)	Cyperaceae	Yes	Usha *et al*., 2005
Cyperus compressus (Annual sedge)	Cyperaceae	Yes	Yik and Birchfield, 1979
Cyperus difformis (Variable Flat Sedge)	Cyperaceae	Yes	Bajaj and Dabur, 2000
Cyperus imbricatus (Shingle flatsedge)	Cyperaceae	No	Usha *et al*., 2005
Cyperus iria (Rice flat sedge)	Cyperaceae	Yes	Dabur *et al*., 2004
Cyperus odoratus(Flatsedge)	Cyperaceae	No	EPPO, 2016
Cyperus pilosus (Fuzzy flatsedge)	Cyperaceae	No	EPPO, 2016

Host Scientific name (common name)	**Family**	**Host Presence in PRA area**	***Reference***
Cyperus procerus	Cyperaceae	No	Usha *et al*., 2005
Cyperus pulcherrimus (Elegant sedge)	Cyperaceae	No	Usha *et al*., 2005
Cyperus rotundus (Purple nutsedge)	Cyperaceae	Yes	Khan *et al*., 2004, Dabur *et al*., 2004; Brito *et al*., 2008
Dactyloctenium aegyptium (Crowfoot grass)	Poaceae	Yes	Khan *et al*., 2004
Dactyloctenium annulatum (Kleberg's bluestem)	Poaceae	No	Dabur *et al*., 2004
Desmodium triflorum (Threeflower ticktrefoil)	Fabaceae	No	Roy, 1977
Digitaria filiformis (Slender crabgrass)	Poaceae	Yes	Usha *et al*., 2005
Digitaria longifolia (False couch grass)	Poaceae	No	Ravindra *et al*., 2017
Digitaria sanguinalis (Dewgrass)	Poaceae	Yes	Khan *et al*., 2004
Echinochloa colona (Junglerice)	Poaceae	Yes	Rao *et al*., 1970; Sperandio and Amaral, 1994
Echinochloa colonum (Junglerice)	Poaceae	Yes	Golden and Birchfield, 1965; Ravindra *et al*., 2017
Echinochloa crusgalli (Barnyaed grass)	Poaceae	Yes	Rao *et al*., 1970; Sperandio and Amaral, 1994
Eclipta alba (False Daisy)	Asteraceae	Yes	Rao *et al*., 1970; Dabur *et al*., 2004
*Eclipta prostrata (*Eclipta alba)	Asteraceae	Yes	EPPO, 2016
Eleusine coracana (Finger millet)	Poaceae	Yes	Usha *et al*., 2005
Eleusine indica (Goose grass)	Poaceae	Yes	Rao *et al*., 1970; Ravindra *et al*., 2017
Eragrostis tenella (Feathery eragrostis)	Poaceae	No	EPPO, 2016
Eragrostis unioloides (Chinese lovegrass)	Poaceae	No	Ravindra *et al*., 2017
Fimbristylis complanata	Cyperaceae	No	Usha *et al*., 2005
Fimbristylis dichotoma var. pluristriata (Tall fringe rush)	Cyperaceae	Yes	Usha *et al*., 2005
Fimbristylis littoralis (Lesser fimbristylis)	Cyperaceae	No	Usha *et al*., 2005
Fimbristylis miliacea (Grasslike fimbristylis)	Cyperaceae	No	Rao *et al*., 1970

Host Scientific name (common name)	**Family**	**Host Presence in PRA area**	***Reference***
Fuirena ciliaris	Cyperaceae	No	EPPO, 2016
Fuirena glomerata	Cyperaceae	No	Usha *et al*., 2005
Gamochaeta coarctata (Purple cudweed)	Asteraceae	Si	EPPO 2016
Gamochaeta falcata (Narrow-leaf cudweed)	Asteraceae	No	EPPO 2016
Glycine max (Soybean)	Fabaceae	Yes	Roy, 1977
Gnaphalium coarctatum (Purple cudweed)	Compositae	No	EPPO, 2016
Grangea ceruanoides	Asteraceae	No	EPPO, 2016
Grangea madraspatensis	Asteraceae	No	Rao *et al*., 1970
Hedyotis diffusa (Spreading hedyotis)	Rubiaceae	No	EPPO 2016
Herminium	Orchidaceae	No	EPPO, 2016
Heteranthera reniformis (Mud plantain)	Pontederiaceae	Yes	EPPO, 2016
Hordeum vulgare (Barley)	Poaceae	Yes	Dabur *et al*., 2004
Hydrilla spp.	Hydrocharitaceae	Yes	Ravindra *et al*., 2017
Impatiens balsamina (Garden balsam)	Balsaminaceae	Yes	Bridge *et al*., 2005
Imperata cylindrica (Silver spikegrass)	Poaceae	Yes	EPPO, 2016
Ischaemum rugosum (Saramollagrass)	Poaceae	No	Usha *et al*., 2005
Jussieua repens	Onagraceae	No	Rao *et al*., 1970
Kyllinga brevifolia (Mullumbimby couch)	Cyperaceae	No	EPPO, 2016
Kyllinga gracillima (False green kyllinga)	Cyperaceae	No	EPPO, 2016
Lactuca sativa (Salad)	Asteraceae	Yes	Bridge *et al*., 2005
Leersia hexandra (Tiger's-tongue grass)	Poaceae	No	EPPO, 2016
Leucas lavandulifolia	Lamiaceae	No	EPPO, 2016
Lindernia	Linderniaceae	No	EPPO, 2016
Ludwigia	Onagrceae	No	EPPO, 2016
Ludwigia adscendens (Floating water primrose)	Onagrceae	No	EPPO, 2016
Lycopersicon esculentum (Tomato)	Solanaceae	Yes	Bridge *et al*., 2005

Host Scientific name (common name)	**Family**	**Host Presence in PRA area**	***Reference***
*Melilotus alba (*Yellow sweetclover)	Papillionaceae	Yes	Dabur *et al*., 2004
Monochoria vaginalis (Pickerel weed)	Pontederiaceae	No	Bridge *et al*., 2005
Murdannia keisak (Marsh dewflower)	Commelinaeae	Yes	EPPO, 2016
Musa (Banana)	Musaceae	Yes	Reversat and Soriano, 2002
Musa acuminate (Dwarf banana)	Musaceae	No	EPPO, 2016
Oplismenus compositus (Armgrass)	Poaceae	No	Roy, 1977
Oryza sativa (Rice)	Poaceae	Yes	EPPO, 2016
Oxalis corniculata (Procumbent yellow wood sorrel)	Oxalidaceae	Yes	EPPO, 2016
Panicum	Poaceae	Yes	EPPO, 2016
Panicum dichotomiflorum (Fall panicgrass)	Poaceae	Yes	EPPO, 2016
Panicum miliaceum (Millet)	Poaceae	Yes	Roy, 1977
Panicum repens (Torpedograss)	Poaceae	Yes	Sperandio and Amaral, 1994
Panicum sumatrense (Hilo grass)	Poaceae	No	EPPO, 2016
Paspalum sanguinola	Poaceae	No	Rao *et al*., 1970
Paspalum scrobiculatum (Ricegrass paspalum)	Poaceae	No	Usha *et al*., 2005
Pennisetum glaucum (Bulrush millet)	Poaceae	Yes	EPPO, 2016
Pennisetum typhoides (Pearl millet)	Poaceae	No	Roy, 1977
Pennisetum pedicellatum (Deenanathgrass)	Poaceae	No	EPPO, 2016
Petunia sp.	Solanaceae	No	Bridge *et al*., 2005
Phaseolus vulgaris (Common bean)	Fabaceae	No	Birchfield, 1964
Phlox drummondii (Annual phlox)	Polemoniaceae	No	Bridge *et al*., 2005
Phyllanthus urinaria (Leafflower)	Euphorbiaceae	No	Rao *et al*., 1970
Physalis minima (Wild cape gooseberry)	Solanaceae	No	Khan *et al*., 2004
Pisum sativum (Garden pea)	Fabaceae	Yes	Bridge *et al*., 2005
Poa annua (Annual bluegrass)	Poaceae	Yes	Sperandio and Amaral, 1994
Portulaca oleracea (Common purslane)	Portulacaceae	Yes	Roy, 1977
Ranunculus (Buttercup)	Ranunculaceae	Yes	EPPO, 2016

Host Scientific name (common name)	Family	Host Presence in PRA area	*Reference*
Ranunculus pusillus (Low spearwort)	Ranuncolaceae	Yes	Yik and Birchfield, 1979
Rungia parviflora	Acanthaceae	No	EPPO, 2016
Saccharum officinarum (Sugarcane)	Poaceae	Yes	Bridge *et al.*, 2005
Sacciolepis indica (Glenwood grass)	Poaceae	No	EPPO, 2016
Scirpus articulatus	Poaceae	No	Usha *et al.*, 2005
Schoenoplectus articulatus (SCPAR)	Cyperaceae	No	EPPO, 2016
Scoparia dulcis (Licorice weed)	Plantaginaceae	No	Roy, 1977
Setaria italica (Foxtail millet)	Poaceae	Yes	Bridge *et al.*, 2005
Sida acuta (Broom grass)	Solanaceae	No	Ravindra *et al.*, 2017
Solanum lycoperisicum (Tomato)	Solanaceae	Yes	Rao *et al.*, 1970
Solanum melongena (Eggplant)	Solanaceae	Yes	Bridge *et al.*, 2005
Solanum nigrum (Black nightshade)	Solanaceae	Yes	EPPO, 2016
Solanum sisymbriifolium (Dense-thorned bitterapple)	Solanaceae	Yes	EPPO, 2016
Solanum tuberosum (Potato)	Solanaceae	Yes	EPPO, 2016
Sorghum bicolor (Sorghum)	Poaceae	Yes	Bridge *et al.*, 2005
Spergula arvensis (Corn spurry)	Caryophyllaceae	Yes	Dabur *et al.*, 2004
Sphaeranthus sp.	Asteraceae	No	Usha *et al.*, 2005
Sphaeranthus senegalensis	Asteraceae	No	EPPO, 2016
Sphenoclea zeylanica (Wedgewort)	Sphenocleaceae	No	Usha *et al.*, 2005
Spinacia oleracea (Spinach)	Amaranthaceae	Yes	Bridge *et al.*, 2005
Sporobolus diander (Tussock dropseed)	Poaceae	No	Khan *et al.*, 2004
Stellaria media (Chickweed)	Caryophyllaceae	Yes	Roy, 1977
Trifolium repens (White clover)	Fabaceae	Yes	Bridge *et al.*, 2005
Trigonella polyceratia (Fenugreek)	Fabaceae	No	Dabur *et al.*, 2004
Triticum aestivum (Wheat)	Poaceae	Yes	Rao *et al.*, 1970
Urena lobata (Aramina fibre plant)	Malvaceae	Yes	EPPO, 2016
Vandellia sp.	Linderniaceae	No	Rao *et al.*, 1970
Vernonia cinerea (Purple fleabane)	Asteraceae	No	EPPO, 2016
Vicia faba (Broad bean)	Fabaceae	Yes	Bridge *et al.*, 2005
Vigna mungo (Black gram)	Fabaceae	No	Bridge *et al.*, 2005

Host Scientific name (common name)	Family	Host Presence in PRA area	*Reference*
Vigna radiata (Green gram)	Fabaceae	No	Bridge *et al.*, 2005
Vigna unguiculata (Cowpea)	Fabaceae	No	Bridge *et al.*, 2005
Zea mays (Maize)	Poaceae	Yes	Bridge *et al.*, 2005

7.1 Main host

Rice: *Italy is the largest rice producer and exporter in the European Union. Rice cultivation is mostly located in Northern Italy (Piedmont, Lombardy, Emilia-Romagna and Veneto regions) where water is relatively abundant, and the rice crop can be raised in flooded fields. Approximately 84 % of rice varieties grown in Italy are Japonica, while the remainder is Indica.*
In 2017, the total area of rice crops cultivated in Italy amounted to 229,546.80 ha, with a 2% decrease compared to 2016 while, in 2018, the total area of rice crops cultivated in Italy, amounted to 217,195 ha, with a 5.4% decrease compared to 2017 (Source: Ente Nazionale Risi). The EU data, referred to 2017 are showed in Table 3.

Table 3. *Main EU Countries producing rice in 2017. (Source: FAOSTAT http://www.fao.org/faostat/en/#data/QC, * Ente Nazionale Risi)*

EU Country	Area of crops cultivated (ha)	Rice production (tons)	Percentage production (%)
Italy *	229,547	1,549,465	53,3
Spain	107,604	835,178	28,7
Greece	30,900	185,250	6,4
Portugal	28,944	179,777	6,2
France	17,452	85,408	2,9
Bulgaria	10,434	58,523	2,0
Romania	9,130	42,810	0,1
Hungary	2,762	9,528	0,3

7.2 Minor hosts (Table 4)

- ***Wheat:*** *among the other host plants of* Meloidogyne graminicola, *wheat is the most cultivated crop in Italy. In northern Italy it is mainly cultivated common wheat, while most of the durum wheat crop is grown further south, in the region of Puglia.*
- ***Maize, Soybeans and Sorghum:*** *90% of Italy's maize production and essentially all the soybean production is in the valley of the Po river. Maize crop area in Italy has been decreasing, due primarily to relatively low prices and high cost of production. Where the maize crop areas have been decreased the fields now are cultivated with durum wheat and sorghum but mostly soybeans crops.*
- ***Barley:*** *this crop is cultivated in Italy mainly for animals feeding and in small part for human food. In recent years, industrial use (malting and brewing) tends to increase in importance. The barley cultivation area is wider than all other cereals, in fact there are varieties that can ripen in north areas (e.g. in the mountainous Trentino and Friuli-Venezia Giulia regions) and others in hot-arid zones.*
- ***Millet:*** *is one of the most drought tolerant crops known. In Italy the importance of these crops has decreased more and more, since their production is mainly destined to feeding birds. Millet cultivation is sporadic and marginal, and it is in those areas where it is more difficult to grow wheat. Data referred to cultivation area (ha) and production (tons) are not available.*

- ***Cabbages:*** *comprising several cultivars of* Brassica oleracea, *it is the most popular winter vegetable cultivated in Italy. Except in Valle d'Aosta, in all Italian regions at least one variety of cabbage is cultivated.*
- ***Onion:*** *in Italy, the regions most involved in the cultivation of onion are Emilia Romagna, Piedmont, Sicily, Veneto, Puglia, Campania and Umbria, but in the vegetable gardens this plant is cultivated in all Italian regions.*

Table 4. *Minor hosts of* Meloidogyne graminicola. *Area of crops cultivated and production in 2017 (Source: ISTAT http://agri.istat.it/sag_is_pdwout/index.jsp)*

Crop	Area of crops cultivated (ha)	Production (tons)
Barley	250,526	984,281
Cabbages	29,807	661,405
Maize	645,742	6,048,498
Millet	Data not available	Data not available
Onion	12,248	410,535
Sorghum	40,901	240,694
Soybeans	322,417	1,019,780
Wheat	1,806,572	6,966,464

8. Pathways for entry

Possible pathways *(in order of importance)*	**Short description explaining why it is considered as a pathway**	Pathway prohibited in the PRA area?	Pest already intercepted on the pathway?
Host plants for planting with roots and soil or growing media	*The nematode is associated only with the roots of its host plants or with soil (or growing media).* *Rice is not traded as plants for planting, but some other host plants can be imported with soil or pot (such as ornamental plants).*	No	No
Non-host plants for planting with soil or growing media attached (including tubers, rhizomes and bulbs, corms)	*Many non-host plants for planting with root-ball or in pots can be imported in Italy. Legislation requirements lay down that the soil or the growing medium should be the minimum to sustain plant vitality and treated before the export.* *Recently, EWG and EFSA concluded that this current EU measures are insufficient to prevent the risk of entry of pests and intercontinental movement of soil with plants for planting is high risk for plant health (EFSA, 2015).* *If non-host plants, bulbs, tubers etc. are used for planting, the nematode might be present in the growing medium or associated to these commodities if they have been grown in infested soil and contain soil residues.*	No	No

*Soil/growing media**	*Soil and growing media are considered a pathway because it can harbour numerous quarantine pests and some other growing media are also recognized pathways for the introduction and spread of quarantine pests. The pest risk of growing media in association with plants for planting depends on factors related to both the production of the growing media and the production of the plants, as well as the interaction between the two (ISPM 40). Soil or growing medium may also contain fragments of infected roots carrying all life stages. Eggs, second-stage juveniles and males can be found in the soil or growing medium in which infected host plants have been grown.*	No	No
Seeds	*Seeds are not considered a pathway because* M. graminicola *couldn't be associated with seed, but sometimes soil and plant debris are present inside the seed lot*	No	No
Waterbirds	*Migratory flyway waterbirds play an important and overlooked role as vectors because they can transport soil, plant and invertebrate propagules between locations at a variety of spatial scales.*	No	No
Machinery, vehicles or other equipment	*If machinery or other agricultural material are used in fields infested by* M. graminicola, *it may carry infested soil or infected root fragments.* Meloidogyne graminicola *is likely to survive at least for some months. If machinery carrying infested soil is used in the field,* M. graminicola *may be transferred to soil in which host plants are grown. This pathway is also relevant for local spread.*	No	No
Travellers	*Travellers coming from infested areas may transport the nematode (e.g. on hiking shoes, collected plants with adhering soil)*	No	No

**According to ISPM No 5 (FAO, 2013a), a growing medium is 'any material in which plant roots are growing or intended for that purpose'. Soil is not defined in ISPM No 5, but a definition is given in a draft ISPM on 'International movement of growing media in association with plants for planting' (FAO, 2017).*

The following pathways are considered unlikely:

- *Plants for planting without roots (non-rooted cuttings, seeds).* Meloidogyne graminicola *infests only roots and may otherwise only be associated with growing medium.*
- *All other host without roots.*
- *Plant parts without roots such as: wood, bark, fruit (including vegetables, pods), flowers, leaves, branches, seeds, grains.*

Rating of the likelihood of entry	Low ☐	Moderate ☐	**High X**
Rating of uncertainty	Low ☐	**Moderate X**	High ☐

9. Likelihood of establishment outdoors in the PRA area

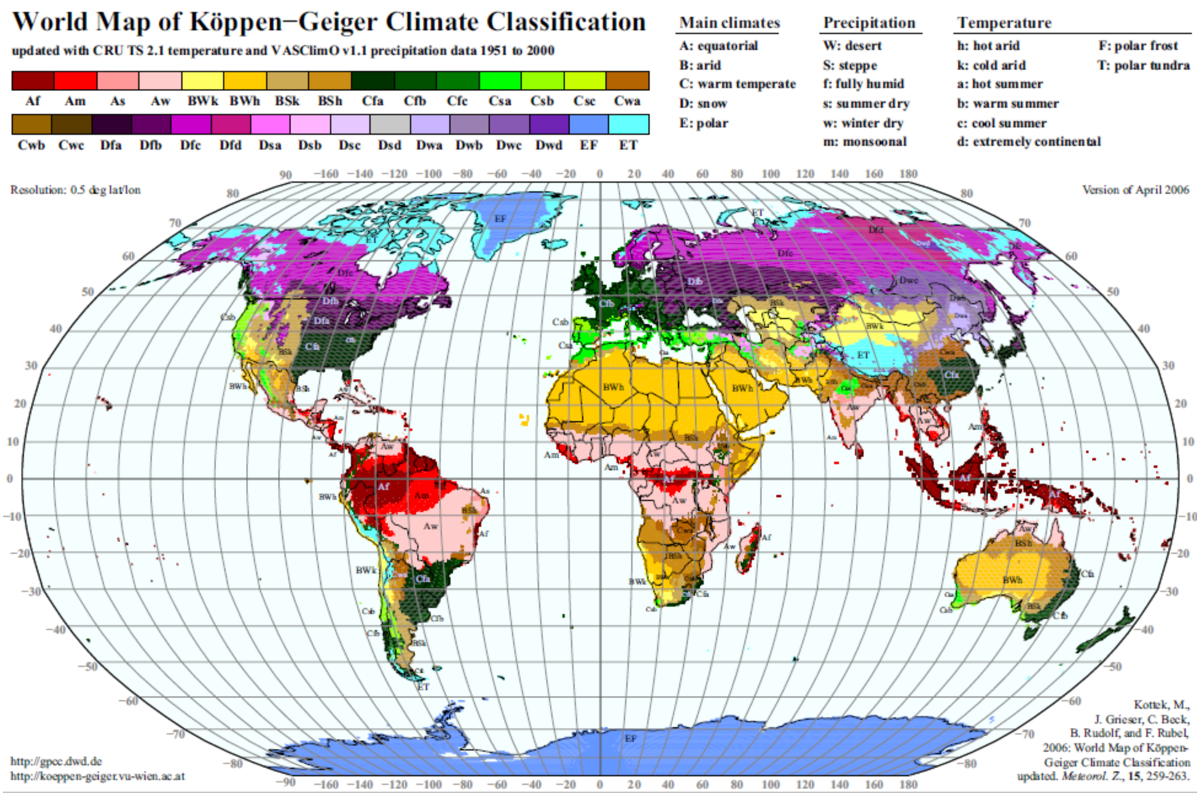
The pest has already established outdoors in the PRA area, because it was found in Northern Italy, in July 2016 in Piedmont and in May 2018 in Lombardy region. The likelihood of establishment within the PRA area overall is therefore high with a low uncertainty, so more details need to be considered in order to determine the endangered area.

9.1 Climatic suitability

Survival of the rice root-knot nematode is greater at moderate temperatures (Soomro, 1994) and in flooded soils (Padgham et al.*, 2003). In India, juvenile populations of* M. graminicola *in soil were found more during December to February when soil temperatures were 20.9°C or less. Populations were found less in March, July and August and very less in April, May and June when the soil temperature was 31°C. Maximum galls on rice roots were found during January to March and egg masses during February to March. Soil temperatures of 23.5°C or less were found most favourable for galls formation (Rao and Israel, 1971).*

The rice European regions are located between 35° and 45° North latitude. This is the climatic limit for cultivation of rice, that is originally a tropical species. One crop per year is grown, from April to October.

Figure 1. *World Map of Köppen-Geiger climate classification updated with mean monthly CRU TS 2.1 temperature and VASClimO v1.1 precipitation data for the period 1951 to 2000 on a regular 0.5 degree latitude/longitude grid.*

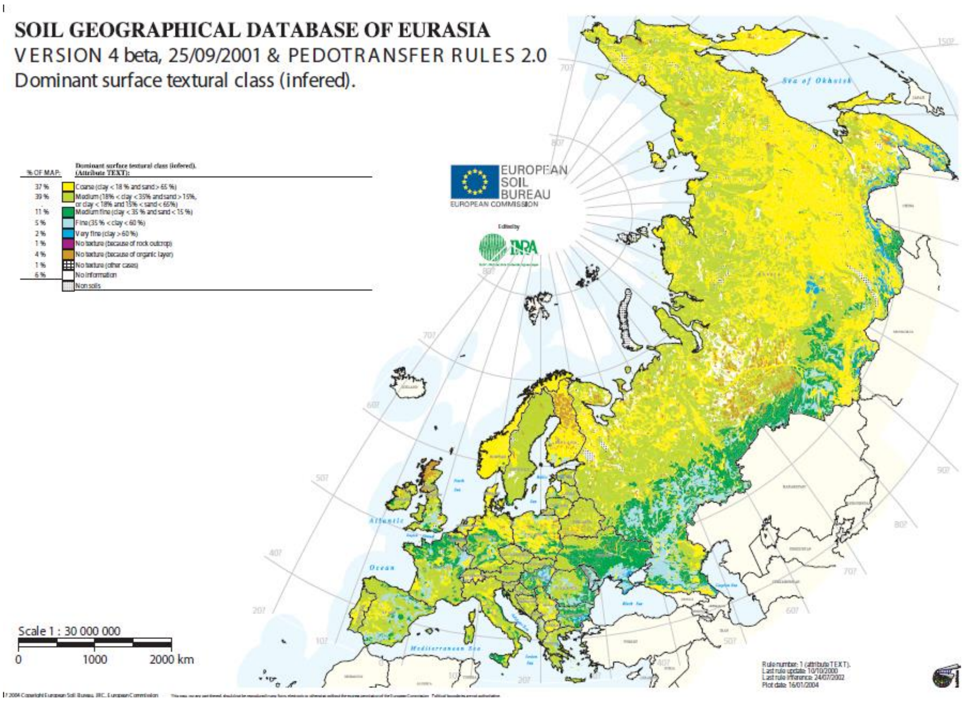


According to the World Map of Köppen-Geiger climate classification, Italy is within the Mediterranean climate that is characterized by warm, dry, clear days and a long growing season (Fig.1). This climate is favourable for high photosynthetic rates and high rice yields, while its low relative humidity throughout the growing season reduces the development, severity and importance of rice diseases. Consequently, suitable climatic conditions outdoors probably occur in the PRA area and they will not be a limiting factor to the establishment of the pest.

9.2 Soil and other abiotic factors

Soil is an important factor for root-knot nematodes. Rao and Israel (1972b) verified that clayey soils were less suitable to this type of nematode infection. With an increase in 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 (in which the available soil nutrients range from moderate to low and water holding capacity is low) favour the development of the nematode. According to Braasch et al. *(1996),* Meloidogyne *spp. can occur on a wide range of soil types, but their association with crop damage is more readily observed in sandy soils (because of the limitation of nutrients and water). It has been observed that waterlogged condition in the direct seeded rice or transplanted crop had no detrimental effects on the survival of the endoparasitic stages (Prasad* et al.*, 1985). Soriano* et al. *(2000) found greater damage to rice varieties in sandy soil than in clay soil. As can be seen from the soil map, the Italian rice fields are mainly characterized by coarse and medium soils.*

Figure 2. *European Soil Database Mapshttp://esdac.jrc.ec.europa.eu/ESDB_Archive/ptrdb/texta3.pdf Dominant surface textural class*



9.3 Host plants

Apart from rice plants, many host plants of M. graminicola *occur in the PRA area, in a wide variety of environments. In particular, dense populations of infected volunteer rice plants lead to a high risk of severe infection and damage in such fields as self -grown, while sprouting rice maintains nematode population densities at damaging levels from one season to the next. However, weeds growing in rice fields, especially within self-sprouted rice fields, may also harbour* M. graminicola *and allow the nematodes to survive in the absence of a rice crop (Medina* et al.*, 2009). Removal of such infected self-grown and weeds may help to reduce the severity of nematode infestation in the fields (Padgham* et al.*, 2004).*

9.4 Other elements relevant for establishment

Many natural antagonistic organisms attack root-knot nematodes (Kerry, 1987) including M. graminicola*, but no specific organisms have been selected or recommended for control of this species in the field. Simon and Anamita (2011) noted that the galls developed in roots of rice plants treated with two nematophagous fungi (*Arthrobotrys oligospora *and* Dactylaria eudermata*) were young with fewer number of females, resulting less eggs and J2s indicating delayed infection. This also indicated that the* *multiplication of the nematode was also arrested in the plant roots treated with these fungi. From the observations these fungi trapped and killed the infective J2 in the infested soil.*

Rating of the likelihood of establishment outdoors	*Low □*	*Moderate □*	***High X***
Rating of uncertainty	***Low X***	*Moderate □*	*High □*

10. Likelihood of establishment in protected conditions in the PRA area

There is no information on whether M. graminicola *is found in glasshouses. However, host experiments were conducted in glasshouses on rice, weed, crop, and ornamental plants (Yik and Birchfield, 1979). The establishment in protected conditions is therefore possible. This nematode reduced the rice yield by more than 17% in a greenhouse experiment and the yield losses might go as high as 80% (Tandingan* et al.*, 1996; Soriano* et al.*, 2000). Severe infection of root-knot nematodes in the nursery leads to the possibility of widespread nematode dispersal in the field as rice seedlings are grown in nurseries and then transplanted in the fields. Also, the use of infested seedlings may result in greater infestation and damage to rice plants in the field (Duxbury, 2001).*

Rating of the likelihood of establishment in protected conditions	*Low □*	***Moderate X***	*High □*
Rating of uncertainty	*Low □*	***Moderate X***	*High □*

11. Spread in the PRA area

No specific data were found for M. graminicola*, but the capacity for natural movement of nematodes, included other* Meloidogyne *species is very limited. According to Tiilikkala* et al. *(1995), free-living second-stage juveniles can move 1-2 m at maximum per year (this probably covers both horizontal movement (away from the host), and vertical movement (staying close to the host). In general,* Meloidogyne *species are always associated with the roots of plants.* M. graminicola *can spread with the growing root system of its hosts, but it does not spread with seed or chaff. (Gaur, 2003).*

Spread by irrigation is possible in PRA area, because the flooding of the paddy fields is controlled and regulated through a system of irrigation ditches, canals and tiny dikes. The flooding ensures a steady water supply for the plants and – more importantly – provides thermal insulation to smooth out differences in temperature between night and day. Water flowing from one infested field to others nearby is likely to could disperse the pest at short and medium distances. In general, nematodes spread by water depends on resistance of the nematode to submersion in water. Survival of the rice root-knot nematode is greater in flooded soils (Padgham et al.*, 2003).*

Nematodes are disseminated in mud or plant debris clinging to birds and other animals. Migratory waterbirds play an important and overlooked role as vectors because they can transport plant and invertebrate propagules between locations at a variety of spatial scales. Waterbirds can disperse alien plants (both aquatic and terrestrial) and invertebrates both via their guts and by carrying them on the outside on feathers, feet or beaks (Reynolds et al.*,2015). Rice fields are used by large numbers of a wide diversity of bird species; agricultural flooded areas in northwestern Italy support 25% of the Italian population of Eurasian Bittern* (Botaurus stellaris) *(Longoni, 2010). Furthermore, small colonies of the Black-headed Gull* (Larus ridibundus)*, Black-tailed Godwit* (Limosa limosa)*, Black Tern (*Chlidonias niger)*, and White-winged Tern* (Chlidonias leucopterus) *nest occasionally within rice fields (Fasola and Ruiz 1996). The Mallard* (Anas platyrhynchos) *and Common Moorhen* (Gallinula chloropus) *often nest along irrigation ditches. rice fields are the main foraging habitat for six heron species that breed in the deltas of Po River (Czech and Parsons, 2002).*

At medium and long-distance M. graminicola *may be moved with plants for planting (mostly hosts with roots) and soil, on its own or carried on machinery or tools. Machinery contaminated with infested soil is known to be a possible pathway for other species in this genus (EPPO/CABI, 1997) and may play a role in local spread. Shoes (gardeners' or trekking shoes) can carry* M. graminicola *when the soil or infected roots are exposed.*

Spread can be contained in agricultural areas by taking appropriate hygienic measures (cleaning machinary, tools, shoes, etc) and prohibit the transportation of soil (or growing media) and infected plants. Moreover, already infested areas should be precisely demarcated and the intensity of soil sampling in suspected areas or in fields, bordering the infested areas should be increased to map the infestation.

Rating of the magnitude of spread	*Low* ☐	***Moderate X***	*High* ☐
Rating of uncertainty	*Low* ☐	***Moderate X***	*High* ☐

12. Impact in the current area of distribution

Rice root-knot nematode, M. graminicola *is a pest of international importance to rice around the world (MacGowan and Langdon 1989) and it is one of the great concerns for yield loss due to nematode infestation in rice and wheat crops under rice-wheat cropping system.*
Very limited information was found on economic and environmental impact.

12.1 Impact in different countries

Africa:
In Africa, M. graminicola *has been reported once in South Africa on grass roots of* Paspalum *sp. and was only identified according to morphological characteristics (Kleynhans 1991). In 2016, the presence of* M. graminicola *was reported for the first time on rice in Madagascar. Rice is the major crop produced in Madagascar, but no further information is available to date.*

America:
No data were found about yield losses or environmental impact.

Asia:
The rice-wheat cropping system is very important in Asia. This system covers about 33% of the total rice area and 42% of the total wheat area in four countries (India, Pakistan, Bangladesh and Nepal), and account for one quarter to one third of the total rice and wheat production. Meloidogyne graminicola *has become a constraint in rice production due to rice cropping intensification and increasing scarcity of water (Prasad and Somasekhar, 2009; Somasekhar and Prasad, 2009).*
Despite the ubiquity of M. graminicola *in Asian rice production, estimates of yield loss under natural infestations are few and have been limited to upland rice systems (Arayarungsarit, 1987; Netscher and Erlan, 1993)*

In India, outbreak of M. graminicola *infestation in kharif rice has been witnessed in around 800 ha in Mandya district of Karnataka (Prasad* et al.*, 2001) and many parts of India like West Bengal, Orissa, Assam, UP, Himachal Pradesh, etc. Moreover, it has been seen that* M. graminicola *can cause up to 21 per cent yield loss in rainfed or well drained soils throughout the country (Prasad* et al.*, 1987). A negative impact of* M. graminicola *on growth and yield of lowland rainfed rice in Bangladesh and aerobic upland rice in Nepal and India have been reported. In* M. graminicola *infested upland rice fields, nematicide application resulted in a yield increase of 12% to 33% in Thailand (Arayarungsarit, 1987) and 28% to 87% in Indonesia (Netscher and Erlan 1993) whereas under simulated upland conditions, yield losses due to* M. graminicola *ranged from 20% to 80% (Plowright and Bridge 1990). In* M. graminicola *infested lowland rainfed rice, nematicide application resulted in a yield increase of 16% to 20% in Bangladesh (Padgham* et al. *2004) compared to no nematicide treated field, and in simulations of intermittently flooded rice, yield losses from* M. graminicola *ranged from 11% to73% (Soriano* et al.*, 2000).*

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

13. Potential impact in the PRA area

Will impacts be largely the same as in the current area of distribution? **Yes** /No

Italy is Europe's most important rice producer, with 217,195 ha of rice in 2018 (Ente Nazionale Risi). There, cultivation is concentrated in the north-western portion of the Po River Plain, where a complex hydro-geological structure, composed of hundreds of fountain heads, facilitates the flooding of fields. The Po River Delta, although a smaller area, also hosts many paddy fields (Fig.2).

In next years, this pest is likely to have major direct economic losses, environmental impact and social impact, by causing damage in the PRA area rice fields. If the nematode were to spread in the PRA area, the impacts in the PRA area would be expected to be like those in Asia.

Figure 3. *Distribution of paddy fields in Italy. From http://www.enterisi.it/Fiore/index.htm*

Rating of the magnitude of impact in the current area of distribution	*Low* ☐	***Moderate X***	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* ☐	***High X***

14. Identification of the endangered area

The pest has already established in limited areas of Italy. Climatic conditions will not be a limiting factor to the establishment of the pest. It may establish and cause damage wherever there are hosts.

15. Overall assessment of risk

Meloidogyne graminicola *is already established in Italy but only in rice fields. This pest has been found associated with rice plants and some weed plants. Internationally, its spread is more likely to occur through the movement of infested plants for planting and soil or growing medium from Asia. The likelihood of entry with machinery contaminated with infested soil was considered as low with a*

moderate uncertainty; and with non-host plant parts that may have growing medium attached (such as roots, tubers, bulbs), for consumption or processing, and with travellers as low with a low to moderate uncertainty.
Inside the PRA area, the natural spread of this pest is limited. Spread will mostly occur through human assisted pathways, with soil or growing media, on its own or carried on machinery or tools, with plants for planting. In paddy fields, passive transport may also be facilitated by movements of water, wild animals and waterbirds.
Rice root-knot nematode is a pest of international importance to rice around the world and it is one of the great concerns for yield loss due to nematode infestation in rice and wheat crops under rice–wheat cropping system. This nematode infests many plant species belonging to different families (mainly Poaceae but also Asteraceae, Cucurbitaceae, Fabaceae, Solanaceae) that include plants of economic importance. Due to large host range of M. graminicola *and its ability to survive for long periods in environments with low oxygen render its control very difficult, adequate phytosanitary measures are important.*

Stage 3. Pest risk management

16. Phytosanitary measures

16.1 Measures on individual pathways

Possible pathways ***(in order of importance)***	**Measures identified**
Host plants for planting with roots and soil or growing media	Pest free area Or Pest free place of production Or Pest-free site of production Or Free and new growing medium (e.g. sterilized peat) Or Post-Entry Quarantine (only for experimental material)
Non-host plants for planting with soil or growing media attached (including tubers, rhizomes and bulbs, corms)	Pest free area Or Pest free place of production Or Pest-free site of production Or Free from soil (would apply to plants with roots, as well as tubers, bulbs, corms etc.) Or Free and new growing medium (e.g. sterilized peat)
Soil/growing media	Pest free area Or Pest free site of production Or Sterilized soil (but this is not practical for large consignments)
Seeds	Pest free area Or Pest-free site of production Or The lot shall not contain more than 1 % by weight of soil and debris
Waterbirds	Monitoring routes of migration birds.

Machinery, vehicles or other equipment	Cleaning and disinfecting of machinery, vehicles and other equipment (to ensure freedom from soil) before entering the field (ISPM 41 - International movement of used vehicles, machinery and equipment)
Travellers	Increase publicity to enhance public awareness on pest risks Or Implement passenger inspections

16.2 Eradication and containment

In general, root-knot nematodes are difficult to control and eradicate. In order to control the spread and to minimise the yield losses, specific eradication actions should be considered in case of findings.

- *intensive sampling and testing of soil and all host plants, particularly in the infested area and in buffer zones (100 m around an infested area);*
- *cleaning of machineries, tools and footwears in the passage from the infested plot to the neighbouring ones;*
- *removal and destruction of infested plants, except field crops close to harvesting;*
- *prohibition of host plants cultivation in the infested area;*
- *periodic elimination of host weeds;*
- *infested material should not be moved out from the infested area, including plants with roots (both hosts and non-hosts) that may have been grown in infested soil; soil itself; machineries and tools that may carry soil; footwear;*
- *submerging rice field with water for more than 18 months.*

17. Uncertainty

– *How the pest was introduced in Italy*

– *Possible transfer from rice plant to vegetable crops such as tomato, potato, pepper, salad or cucumber.*

18. Remarks

- *The tolerance of rice cultivars to* M. graminicola *varies with water regime. Early flooding after sowing to limit invasion of roots by the nematode and to promote good establishment of the rice crop, appear necessary to prevent or minimize yield loss due to* M. graminicola *in irrigated and in wet seeded rice. In addition, continuous flooding until the later stage of rice growth seems to reduce the increase in nematode population. In areas where water supply is limited it could be more efficient to keep soil flooded at the beginning rather than later in the cropping season.*
- *Crop rotation with either non-host or poor host crops may serve as an effective option to reduce nematode population in the infested field.*

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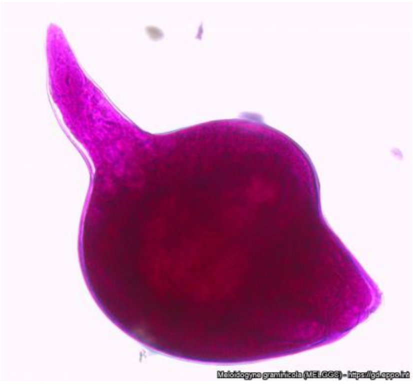
Appendix 1. Relevant illustrative pictures (for information)

<table>
<tr><td>Photo 1 (Meloidogyne graminicola)

Male

Female</td><td>Photo 2 (Symptoms)

</td></tr>
<tr><td>Source/ EPPO DATABASE
https://gd.eppo.int/taxon/MELGGC/photos</td><td>Source/ EPPO DATABASE
https://gd.eppo.int/taxon/MELGGC/photos</td></tr>
</table>