CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

California Pest Rating Proposal for

Meloidogyne mali Itoh, Oshima & Ichinohe 1969

apple root-knot nematode

Current Pest Rating: none

Proposed Pest Rating: A

Kingdom: Animalia, Phylum: Nematoda,
Class: Chromadorea, Order: Rhabditida,
Family: Meloidogynidae

Comment Period: 09/05/2023 through 10/20/2023

Initiating Event:

This nematode has not been through the pest rating process. The risk to California from *Meloidogyne mali*, the apple root-knot nematode, is described herein and a permanent pest rating is proposed.

History & Status:

Background: *Meloidogyne* spp. are obligate, sedentary endoparasites that feed within host plant roots. The effect of root-knot nematodes on plants can be dramatic. As a result of their feeding, large galls or "knots" are formed on the root systems, which impairs the plant's ability to take up water and nutrients from the soil (Chitambar et al., 2018).

Meloidogyne is a name of Greek origin, meaning "apple-shaped female." Adult females, globose and sedentary, are found embedded in their host's roots. They produce eggs within a mass either on the surface of, or within roots. *Meloidogyne* spp. generally reproduce by mitotic parthenogenesis, meaning that males are not necessary and viable eggs can be produced by females alone in the absence of fertilization. Vermiform males are usually rare unless the population is subjected to environmental stress. Eggs hatch in the soil and vermiform juveniles swim to new roots (Mitkowski and Abawi, 2003).

The first-stage juvenile develops within the egg and molts to develop into the second stage. The second-stage juveniles (J2) are the infective stage that hatch from eggs and migrate in rhizosphere soil

to host roots. The J2s penetrate the host roots and establish a specialized feeding site that is formed at the head end of the nematode in response to its feeding. They become sedentary while feeding at the specialized site, increasing in size, and undergoing two more molts and non-feeding stages before developing into mature adult females or vermiform males and completing the life cycle.

The feeding site is a group of plant cells, known as "giant cells", created when the nematode injects secretory proteins that stimulate changes within the parasitized cells. The injected cells rapidly become multinucleate when division occurs without cell wall formation. Giant cells can be very large and act as significant nutrient sinks, producing large amounts of proteins that the nematodes can use. Increases in the production of plant growth regulators from nematode feeding also play a role in this increase in cell size and division. Root cells next to the giant cells enlarge and divide rapidly, resulting in gall formation. Once a female establishes a feeding site as a juvenile, she permanently remains within the plant root, exuding her eggs out into the soil (Perry and Moens, 2013).

In 1969, Itoh et al. described *Meloidogyne mali* from the roots of apple rootstocks (*Malus prunifolia*) from Japan. It is a polyphagous nematode with a very broad host range parasitizing fruit and nut trees, flowering trees, shade trees, woody shrubs, vines, brambles, vegetables, row crops, flowers, weedy plants, and ferns. It is described as one of the most damaging nematodes for apples in Northern Japan, causing stunting and severe decline of trees in orchards (Itoh et al., 1969; Nyczepir and Halbrendt, 1993). In 2000, a nematode was described infecting elms (*Ulmus* sp.) in Italy (Palmisano and Ambrogioni, 2000). Their original description of *M. ulmi* was differentiated from *M. mali* based on characters that generally show high intraspecific variations. *Meloidogyne ulmi* was synonymized with *M. mali* based on morphological and morphometric similarities, with common hosts, and with biochemical and molecular similarities by Ahmed et al. (2013).

There is only one location in the United States where *M. mali* has been detected. In 2016, Eisenback et al. reported that a root sample from a declining hedge of *Euonymus kiautschovicus* at a private residence in Harrison, NY, showed roots disfigured with swellings and galls and contained adult females. They used PCR for the D2-D3 region of the 28S ribosomal RNA gene and the sequences were blasted against GenBank for matches. Although there were a few nucleotide differences between this and other international isolates of *M. mali*, the similarity ranged from 96 to 98%.

Hosts: Reported primarily from woody perennial hosts, the main hosts are *Malus* (apple), *Morus* (mulberry), and *Ulmus* (elm). Other hosts are *Acer palmatum* (Japanese maple), *A. pseudoplatanus* (Sycamore maple), *Arctium lappa* (great burdock), *Brassica napus* (canola), Brassica oleracea (broccoli), *Brassica rapa* (turnip), *Broussonetia kazinoki* (kozo), *B. papyrifera* (mulberry), *Capsicum annuum* (pepper), *Castanea crenata* (chestnut), *Citrullus vulgaris* (watermelon), *Cucumis sativus* (cucumber), *Cucurbita* sp. (squash), *Daucus carota* (carrot), *Dryopteris carthusiana* (narrow buckler fern), *D. filix-mas* (male fern), *Euonymus fortune* (spindle tree), *E. kiautschovicus* (spindle tree), *Fagus sylvatica* (European beech), *Ficus carica* (common fig), *Geranium robertianum* (herb-robert), *Geum coccineum* (avens), *Glycine max* (soybean), *Impatiens parviflora* (small balsam), *Lagerstroemia indica* (crape myrtle), *Maclura tricuspidate* (Chinese mulberry), *Malus prunifolia* (plum-leaf crabapple), *M. pumila* (common apple), *M. sieboldii* (Siebold's crabapple), *Malus* sp. (apple), *Morus australis* (Korean

mulberry), *Prunus* X *yedoensis* (Japanese flowering cherry), *Quercus robur* (oak), *Rosa* sp. (rose), *Rubus idaeus* (garden raspberry), *Solanum lycopersicum* (tomato), *S. melongena* (eggplant), *Sorbus aucuparia* (European mountain ash), *Taraxacum officinale* (dandelion), *Taxus baccata* (English yew), *Trifolium repens* (white clover), *Ulmus chenmoui* (elm), *U. glabra* (Wych elm), *U. japonica* (Japanese elm), *U. x hollandica* (Dutch elm), and *Urtica dioica* (stinging nettle) (Nemaplex, 2010).

Symptoms: Visible signs of severe plant infestation can be observed both above and below ground. Affected plants often exhibit stunted growth and yellowing leaves. Below ground, the presence of galls is a common indicator of nematode infestation. *Meloidogyne mali* induces galls typical to other root-knot nematodes, up to 0.5 cm in diameter. Galls can become relatively large on older plants, 1-2 cm in diameter. Symptoms in trees only appear when the trees are heavily infested and include early leaf fall and reduced growth (Subbotin et al., 2021).

Transmission: Meloidogyne mali has limited ability to move in the field. Only second-stage juveniles can move within the soil, and their range is typically restricted to a few tens of centimeters per year at most. Unlike other *Meloidogyne* species, *M. mali* (2n=22) males are seen regularly, and it reproduces by amphimixis rather than parthenogenesis (Janssen et al., 2017). The most probable way for *M. mali* to be introduced to a new area is through the transportation of infested or contaminated planting materials. Nematodes can easily be carried by infested host plants or host products. Additionally, the movement of non-host plants intended for planting, like seedling transplants or nursery stock, as well as non-host plant products such as bulbs, tubers, corms, and rhizomes, can contribute to the spread of *M. mali* if they are contaminated with soil infested by the nematode. Another potential pathway for its spread is through the movement of bulk soil. Contaminated irrigation water can also facilitate nematode movement (Chitambar et al., 2018; CABI, 2023).

Damage Potential: This nematode is damaging to woody hosts, especially apple and elm trees. When large root galls are formed, they interfere with the water and nutrient uptake from the soil, reduce growth, and increase the risk of windthrow (CABI, 2023). In Japan, *M. mali* is a significant pest of apple (*Malus domestica/M. pumila*), including rootstocks such as *M. prunifolia*, and cause serious tree decline (Itoh et al., 1969). Plant growth and leaf weights were reduced by 10-20% in infected mulberries (Toida, 1991). In Italy, the UK, and the Netherlands, *M. mali* has been found primarily with elms (*U. chenmoui/U. glabra*) and co-occurs with Dutch elm disease (*Ophiostoma ulmi*) (Prior et al., 2019).

The host range of *M. mali* includes many species of economic importance including other fruit trees, forestry trees and vegetable crops. The potential danger to these caused *M. mali* to be added to the European and Mediterranean Plant Protection Organization Alert List and the quarantine list for several countries.

Worldwide Distribution: America: *United States* (New York). Asia: *Japan, Republic of Korea*. Europe: *Belgium, France, Italy, Netherlands, United Kingdom* (EPPO, 2023).

Official Control: *Meloidogyne mali* is a U.S.-regulated pest meaning if intercepted at the border or at a port, it would be subject to treatment or rejection. It is on the USDA PCIT'S Harmful Organism list for

Canada, Colombia, Indonesia, Morocco, The Republic of Korea, and Timor-Leste (USDA PCIT, 2023). It is on the EPPO's A2 list for the European Plant Protection Organization and is a quarantine pest in Morocco (EPPO, 2023).

California Distribution: none

California Interceptions: none

The risk that *Meloidogyne mali* would pose to California is evaluated below.

Consequences of Introduction:

1) **Climate/Host Interaction:** This nematode is likely to occur wherever its hosts can grow.

   Evaluate if the pest would have suitable hosts and climate to establish in California.

   Score: **3**
   - Low (1) Not likely to establish in California; or likely to establish in very limited areas.
   - Medium (2) may be able to establish in a larger but limited part of California.
   - High (3) likely to establish a widespread distribution in California.

2) **Known Pest Host Range:** The host range includes plants in multiple families.

   Evaluate the host range of the pest.

   Score: 3
   - Low (1) has a very limited host range.
   - Medium (2) has a moderate host range.
   - High (3) has a wide host range.

3) **Pest Reproductive Potential:** Each female can produce hundreds of eggs, but the natural movement of soil-borne nematodes is very limited in undisturbed soils. They are spread easily with agricultural operations that move soil, equipment, and plant materials.

   Evaluate the natural and artificial dispersal potential of the pest.

   Score: 2
   - Low (1) does not have high reproductive or dispersal potential.
   - Medium (2) has either high reproductive or dispersal potential.
   - High (3) has both high reproduction and dispersal potential.

4) **Economic Impact:** Root-knot nematodes are known to be very damaging to agriculture. *Meloidogyne mali* causes the greatest damage to woody plants where it can form large galls on the roots. It is a quarantine pest in the United States and other places.

Evaluate the economic impact of the pest on California using the criteria below.

Economic Impact: A, C, G

A. The pest could lower crop yield.
B. The pest could lower crop value (including increasing crop production costs).
C. The pest could trigger the loss of markets (including quarantines).
D. The pest could negatively change normal cultural practices.
E. The pest can vector, or is vectored, by another pestiferous organism.
F. The organism is injurious or poisonous to agriculturally important animals.
G. The organism can interfere with the delivery or supply of water for agricultural uses.

Economic Impact Score: **3**
- Low (1) causes 0 or 1 of these impacts.
- Medium (2) causes 2 of these impacts.
- High (3) causes 3 or more of these impacts.

5) **Environmental Impact:** Once established, root-knot nematodes are very difficult to eradicate.

Evaluate the environmental impact of the pest on California using the criteria below.

Environmental Impact: E

A. The pest could have a significant environmental impact such as lowering biodiversity, disrupting natural communities, or changing ecosystem processes.
B. The pest could directly affect threatened or endangered species.
C. The pest could impact threatened or endangered species by disrupting critical habitats.
D. The pest could trigger additional official or private treatment programs.
E. The pest significantly impacts cultural practices, home/urban gardening, or ornamental plantings.

Environmental Impact Score: 2
- Low (1) causes none of the above to occur.
- Medium (2) causes one of the above to occur.
- High (3) causes two or more of the above to occur.

Consequences of Introduction to California for *Meloidogyne mali:* High

Add up the total score and include it here. 13
-Low = 5-8 points
-Medium = 9-12 points
-High = 13-15 points

6) **Post-Entry Distribution and Survey Information**: Evaluate the known distribution in California. Only official records identified by a taxonomic expert and supported by voucher specimens deposited in natural history collections should be considered. Pest incursions that have been eradicated, are under eradication or have been delimited with no further detections should not be included.

Evaluation is 'not established'.

Score: 0
-Not established (0) Pest never detected in California or known only from incursions.
-Low (-1) Pest has a localized distribution in California or is established in one suitable climate/host area (region).
-Medium (-2) Pest is widespread in California but not fully established in the endangered area, or pest established in two contiguous suitable climate/host areas.
-High (-3) Pest has fully established in the endangered area, or pest is reported in more than two contiguous or non-contiguous suitable climate/host areas.

7) **The final score is** the consequences of the introduction score minus the post-entry distribution and survey information score: (Score)

Final Score: *Score of Consequences of Introduction – Score of Post Entry Distribution and Survey Information* ***= 13***

Uncertainty:

None

Conclusion and Rating Justification:

Based on the evidence provided above the proposed rating for ***Meloidogyne mali*** **is A.**

References:

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Responsible Party:

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***Comment Period: 09/05/2023 through 10/20/2023**

***NOTE:**

You must be registered and logged in to post a comment. If you have registered and have not received the registration confirmation, please contact us at permits[@]cdfa.ca.gov.

Comment Format:

- Comments should refer to the appropriate California Pest Rating Proposal Form subsection(s) being commented on, as shown below.

  Example Comment:

  Consequences of Introduction: 1. Climate/Host Interaction: [Your comment that relates to "Climate/Host Interaction" here.]

- Posted comments will not be able to be viewed immediately.
- Comments may not be posted if they:

  Contain inappropriate language which is not germane to the pest rating proposal;

  Contains defamatory, false, inaccurate, abusive, obscene, pornographic, sexually oriented, threatening, racially offensive, discriminatory or illegal material;

  Violates agency regulations prohibiting sexual harassment or other forms of discrimination;

  Violates agency regulations prohibiting workplace violence, including threats.

- Comments may be edited prior to posting to ensure they are entirely germane.
- Posted comments shall be those which have been approved in content and posted to the website to be viewed, not just submitted.

Proposed Pest Rating: A
