

EPPO Datasheet: *Meloidogyne chitwoodi*

Last updated: 2020-12-18

IDENTITY

Preferred name: *Meloidogyne chitwoodi*

Authority: Golden, O'Bannon, Santo & Finley

Taxonomic position: Animalia: Nematoda: Chromadorea:
Rhabditida: Meloidogynidae

Common names: Columbia root-knot nematode (US)

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EPPO Categorization: A2 list

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EU Categorization: Quarantine pest ((EU) 2019/2072 Annex II B)

EPPO Code: MELGCH



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HOSTS

M. chitwoodi has a wide host range among monocotyledonous and dicotyledonous crop plants, including weeds and economically important crops. Potatoes (*Solanum tuberosum*), carrots (*Daucus carota*) and tomatoes (*Solanum lycopersicum*) are good hosts, while barley (*Hordeum vulgare*), maize (*Zea mays*), oats (*Avena sativa*), sugar beet (*Beta vulgaris* var. *saccharifera*), wheat (*Triticum aestivum*) and various Poaceae (grasses and weeds) will only maintain the nematode (Santo *et al.*, 1980; O'Bannon *et al.*, 1982; Kuttywayo & Been, 2006; EFSA, 2019). Moderate to poor hosts occur in the Apiaceae, Brassicaceae, Cucurbitaceae, Fabaceae, Lamiaceae, Liliaceae and Vitaceae. According to Best4Soil database, marigold (*Tagetes patula*), strawberry (*Fragaria x ananassa*), linseed (*Linum usitatissimum*), chicory (*Cichorium intybus*) and spinach (*Spinacia oleracea*) are not host of *M. chitwoodi* (Best4Soil, 2020), also marigold and chicory are reported to allow some reproduction (Brinkmann *et al.*, 1996). Besides, several fodder radish cultivars (*Raphanus sativus* var. *oleifera*) are available with very good resistance towards *M. chitwoodi*.

Two races of *M. chitwoodi* have been described, distinguished by slight differences in host range. Race 1 reproduces on carrot but not on lucerne (*Medicago sativa*), whereas race 2 reproduces on lucerne but not on carrot (Santo & Pinkerton, 1985; Mojtahedi *et al.*, 1988). Race 1 occurs worldwide, while race 2 is only reported from the Pacific Northwest in the USA and Mexico (Santo & Ponti, 1985; Cuevas & Sosa-Moss, 1990). Ferris *et al.* (1994), when investigating suitable crops for rotation with potato in the presence of race 1 in USA, recommend the use of *Amaranthus*, lucerne, oilseed rape (*Brassica napus* var. *oleifera*), fodder radish and safflower (*Carthamus tinctorius*). Both races do not reproduce on *Solanum bulbocastanum*, while this wild potato species is used as source for resistance in breeding programs. However, populations of *M. chitwoodi* race 1 have been found to overcome the main resistance gene *Rmcl(blb)* from *S. bulbocastanum* (Mojtahedi *et al.*, 2007).

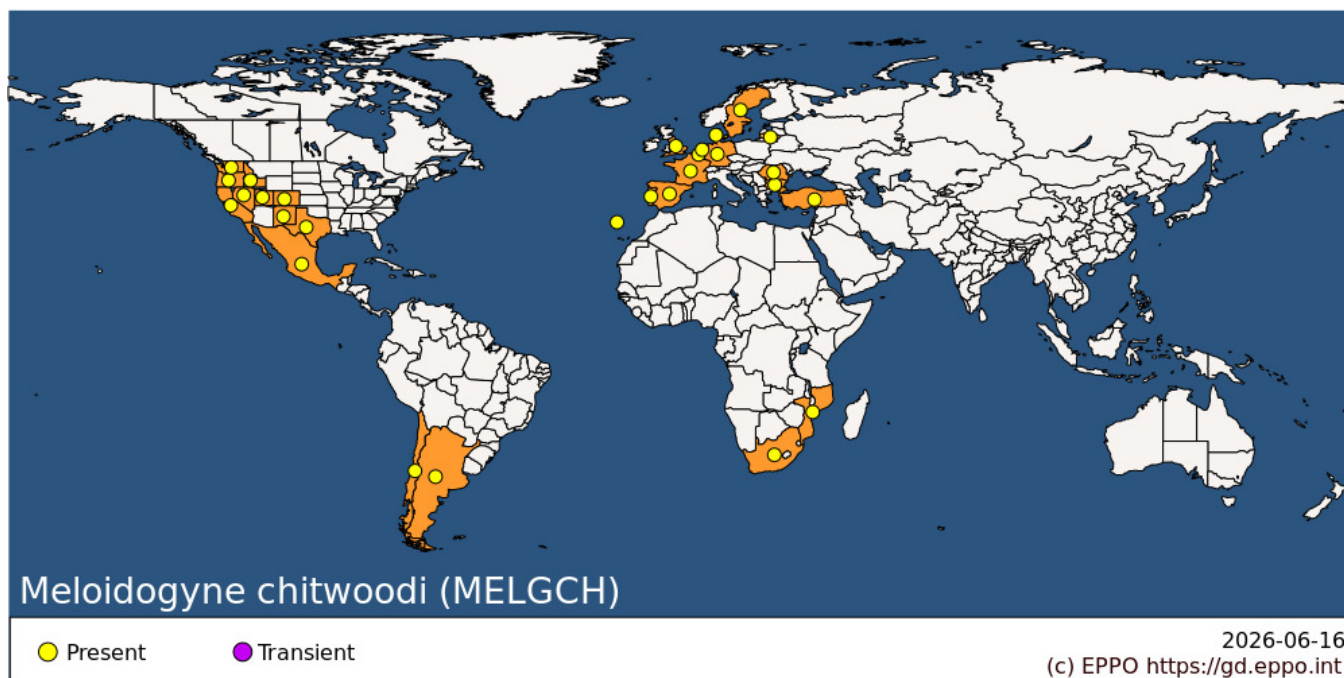
In Europe, host crops recorded to be attacked by *M. chitwoodi* are black salsify (*Scorzonera hispanica*), carrots, cereals, common bean (*Phaseolus vulgaris*), maize, peas (*Pisum sativum*), potatoes, sugar beet and tomatoes (EPPO, 1991). It is expected that many more plant species are hosts of *M. chitwoodi* than currently known, since this is the case also with other, closely related root knot nematodes.

Host list: *Abelmoschus esculentus*, *Acer campestre*, *Acer palmatum*, *Acer platanoides*, *Actaea racemosa*, *Aegilops cylindrica*, *Allium cepa*, *Allium moly*, *Allium porrum*, *Anthemis arvensis*, *Apium graveolens* var. *rapaceum*, *Apium graveolens*, *Arachis hypogaea*, *Arrhenatherum elatius*, *Asclepias syriaca*, *Astragalus cicer*, *Astragalus falcatus*, *Avena sativa*, *Beta vulgaris*, *Borago officinalis*, *Brassica juncea*, *Brassica napus*, *Brassica rapa*, *Bromus tectorum*, *Capsella bursa-pastoris*, *Capsicum annuum*, *Capsicum*, *Chenopodium album*, *Cichorium endivia*, *Cichorium intybus* var. *foliosum*, *Cichorium intybus*, *Cirsium arvense*, *Cirsium vulgare*, *Citrullus lanatus*, *Clematis*, *Coronilla varia*, *Cynodon dactylon*, *Dactylis glomerata*, *Dahlia*, *Dasiphora fruticosa*, *Daucus carota*, *Delphinium*, *Dicentra formosa*, *Echinochloa crus-galli*, *Elymus repens*, *Eragrostis curvula*, *Eragrostis orcuttiana*, *Eragrostis tef*, *Erica cinerea*, *Fagopyrum*, *Festuca rubra*, *Fragaria chiloensis*, *Galinsoga parviflora*, *Geranium* sp., *Gladiolus*, *Gossypium hirsutum*

, *Helianthus annuus*, *Hordeum vulgare*, *Hosta sieboldiana*, *Iris x germanica*, *Iris xiphium*, *Lamium amplexicaule*, *Lamprocapnos spectabilis*, *Lilium hybrids*, *Lolium arundinaceum*, *Lolium multiflorum*, *Lolium perenne*, *Lonicera xylosteum*, *Lotus corniculatus*, *Lupinus albus*, *Medicago falcata*, *Medicago sativa*, *Medicago scutellata*, *Melilotus officinalis*, *Mentha spicata*, *Mentha x gentilis*, *Mentha x piperita*, *Nicotiana*, *Oenothera glazioviana*, *Panicum capillare*, *Persicaria maculosa*, *Petroselinum crispum*, *Phacelia tanacetifolia*, *Phaseolus vulgaris*, *Pisum sativum*, *Poa annua*, *Poa pratensis*, *Raphanus sativus* subsp. *oleiferus*, *Raphanus sativus*, *Salsola kali*, *Scorzonera hispanica*, *Secale cereale*, *Senecio vulgaris*, *Setaria pumila*, *Sinapis alba*, *Solanum lycopersicum*, *Solanum melongena*, *Solanum nigrum*, *Solanum tuberosum*, *Sonchus arvensis*, *Sorghum bicolor*, *Spinacia oleracea*, *Stellaria media*, *Tagetes patula*, *Taraxacum officinale*, *Trifolium pratense*, *Trifolium repens*, *Triticum aestivum* subsp. *aestivum*, *Triticum*, *Valeriana officinalis*, *Vicia sativa*, *Vigna unguiculata*, *Vitis labrusca*, *Vitis vinifera*, *Zea mays*, x *Triticosecale*

GEOGRAPHICAL DISTRIBUTION

M. chitwoodi was originally described in 1980 from potato collected from Quincy, Washington, USA (Golden *et al.*, 1980). At that time, the species was known to occur in the Pacific Northwest of the USA, in certain areas of Idaho, Washington and Oregon. Its common name derives from the Columbia River Basin of South Central, Washington and North Central Oregon where it was first reported. *M. chitwoodi* was first detected in the EPPO region in the 1980s, in the Netherlands, but a review of old illustrations and old specimens of *Meloidogyne* suggests that it may have occurred earlier (in the 1930s) and may have been present throughout the intervening period (EPPO, 1991). It is possible that *M. chitwoodi* has a wider distribution in Europe, than is currently known, remaining undetected, but this is now actively under investigation.



EPPO Region: Belgium, Bulgaria, Denmark, France (mainland), Germany, Lithuania, Netherlands, Portugal (mainland, Madeira), Romania, Spain (mainland), Sweden, Türkiye, United Kingdom (England)

Africa: Mozambique, South Africa

North America: Mexico, United States of America (California, Colorado, Idaho, Nevada, New Mexico, Oregon, Texas, Utah, Washington)

South America: Argentina, Chile

BIOLOGY

The life cycle of *M. chitwoodi* takes approximately 3-5 weeks under favourable conditions. First stage juveniles moult into second stage juveniles within the eggs. Second-stage juveniles hatch from eggs in the soil or on the root

surface and migrate to the roots of host plants. They penetrate the root tips through unsubserved epidermal cells or wounds and move into the cortical region. Soon after entry, nematodes stimulate giant cell and gall formulation in the host tissue and become sedentary. Necrotic lesions occur in the cortex. Juveniles then swell to become sausage-shaped, stop feeding and undergo three rapid successive moults to become adult males or females. Adult males have slender, vermiform bodies; they leave the root and are found free in the rhizosphere or near the protruding body of the female. However, as in the case of other *Meloidogyne* spp., it is probable that males are generally functionless, and reproduction is nearly always parthenogenetic. Adult females have characteristically pear-shaped, pearly white bodies and they are found embedded in host tissue. Eggs are laid by the female in a gelatinous sac near the root surface. In potato tubers, modified host cells form a protective layer or 'basket' around the egg mass and the juveniles as they hatch.

M. chitwoodi passes the winter as eggs or juveniles and can survive extended periods of sub-freezing temperatures. *M. chitwoodi* metabolism becomes active when the soil temperature rises above 5°C. It requires 600-800 degree-days to complete the first generation; subsequent generations require 500-600 degree-days, however, the number of degree-days might vary between crops (Khan *et al.*, 2014). The Northern root-knot nematode *M. hapla*, which is often found in mixed populations with *M. chitwoodi*, requires a similar number of degree-days for development but does not begin development until temperatures rise above 10°C (Pinkerton *et al.*, 1991). In the absence of a suitable host, the population of *M. chitwoodi* usually declines rapidly. Population decline can be up to 80% within one month after potato harvest, but generally is more in the range of 70-90% reduction over three months. Unlike cyst nematodes, *M. chitwoodi* does not have a specific survival stage, but individual second-stage juveniles can survive in the soil for up to 1 year and eggs can survive for up to 4 years (pers. comm. J. Hallmann).

DETECTION AND IDENTIFICATION

Symptoms

Symptoms of *M. chitwoodi* vary according to host, population density of the nematode and environmental conditions. Above-ground symptoms are often not obvious but may consist of varying degrees of stunting, lack of vigour and a tendency to wilt under moisture stress, all leading to reduced yield, while below-ground galling is typical and can vary in size and numbers depending on the host and population density.

The galls produced on potato roots by *M. chitwoodi* differ from those caused by other species of *Meloidogyne*. *M. hapla*, for example, forms small but distinct galls (together with extensive root proliferation) while *M. incognita* forms large, easily noticeable galls. The symptoms caused by *M. chitwoodi* are often not easily detected and are more apparent in some cultivars than in others; tubers may, in some cases, be heavily infected without visible symptoms. When present, the galls appear as small, raised swellings on the tuber surface above the developing nematodes. A number of galls may be concentrated on one area of the tuber or single galls may be scattered near eyes or lesions. Internal tissue below the gall is necrotic and brownish. Adult females are visible just below the surface as glistening, white, pear-shaped bodies surrounded by a brownish layer of host tissue. Potato roots may also be infested, but this is difficult to detect without a magnifying lens, as little or no galling occurs, even in heavy infestations. The spherical bodies of females may protrude from the surface of small rootlets surrounded posteriorly by a large egg-filled sac which becomes dark-brown with age. On carrots and black salsify, severe galling occurs in close proximity to lenticels. The extent of galling is cultivar dependent and affected by the population density of *M. chitwoodi* and the existing environmental conditions. In other host crops, root galls and reduced root growth are also observed, decreasing yields and marketability. Gall formation occurs on most cereals but is more noticeable on wheat and oats than on barley or maize. In tomatoes, *M. chitwoodi* produces root galls in some cultivars but not in others.

Morphology

Adult males and the second-stage juveniles are vermiform and motile, similar in general appearance to free-living soil nematodes. Females are characteristically pear-shaped, pearly-white and sedentary. The male is 887-1268 µm in length and 22-37 µm in width with a slight taper at each end. The tail is short, 4.7-9.0 µm and rounded. Cuticular annules are distinct and are more prominent near each end. The female is 430-740 µm in length and 344-518 µm in width. Second-stage juveniles are 336-417 µm in length and 12.5- 15.5 µm in width, tail short, 39-47 µm, scarcely

tapered and hyaline. Eggs are 79-92 µm in length and 40-46 µm in width (Golden *et al.*, 1980).

Identification is best carried out according to the description in the EPPO Diagnostic Standard PM 7/41 *Meloidogyne chitwoodi* and *M. fallax* (EPPO, 2016). This Standard provides all relevant morphological information and molecular tools for an accurate identification and discusses possible confusion with similar species, such as *M. fallax* and *M. minor*.

Detection and inspection methods

Specific guidance on the sampling of soil and potato tubers is given in the EPPO Standards PM 9/17 (EPPO, 2013b), PM 3/71 (EPPO, 2007) and PM 3/69 (EPPO, 2019a). Populations in the soil rapidly decline in the absence of a host and nematodes reproduce better on a good host. Therefore, detection of the nematodes through field inspection and soil sampling is more sensitive if done as close as possible to the time of harvest of a host crop, targeting particularly susceptible plants (EPPO, 2013b). In each lot of potato (typically 25 tonnes), 200 tubers are randomly sampled and processed (EPPO, 2019a).

Nematode extraction and identification should be carried out according to EPPO Diagnostic Standards PM 7/119 (EPPO, 2013a) and PM 7/41 (EPPO, 2016).

External symptoms on tubers are obvious in the case of heavy infestations (EPPO, 2019a) but, where nematode numbers are low or in the early stages of infection, such symptoms are not obvious. Clearing and staining of the tissues can show the presence of nematodes (Hooper, 1986) but this can be a laborious procedure. Storage of lightly infested tubers may lead to the development of obvious external symptoms.

PATHWAYS FOR MOVEMENT

M. chitwoodi has very limited potential for natural movement; only second-stage juveniles can move in the soil and, at most, only a few tens of centimetres. The most likely pathway for introducing *M. chitwoodi* into a new area is through the movement of infested planting material (e.g. seedling transplants, nursery stock). Non-host plant products (e.g. bulbs, tubers, corms and rhizomes), equipment and machinery which are contaminated with soil infested with *M. chitwoodi* could also result in spread (EPPO, 2013b). Soil as such is also a possible pathway. Nematode movement can also be facilitated by contaminated irrigation water.

PEST SIGNIFICANCE

Economic impact

In most cases, *M. chitwoodi* causes only limited or no yield reduction, however, severe quality losses can occur on certain products, such as potatoes, black salsify and carrots. If the level of infection is high, complete rejection of these crops is possible. Due to these quality losses, the threshold level for those crops is usually defined at around the detection level, i.e. 1 juvenile/100 mL soil (Heve *et al.*, 2015). For potato, 5% visual symptoms on the tuber generally make the crop commercially unacceptable. Similar threshold levels apply to carrot and black salsify, but in practice, many companies apply zero tolerance of symptoms.

Effects on other crops are not as marked nor as well documented. In many cases, potential yield losses have been documented under greenhouse conditions, such as for wheat, barley, oat, maize, bean and pea (Santo & O'Bannon, 1981; Santo & Ponti, 1985), but the impact of *M. chitwoodi* on such crops in practice is generally considered to be minor (EFSA, 2012).

In countries where *M. chitwoodi* is regulated, traded plants and plant products infested with *M. chitwoodi* may need to be destroyed.

Control

Control of *M. chitwoodi* can be challenging and could focus on host suitability, damage thresholds, effect of fallow, the use of green manure crops and time of sowing. Crop rotation is difficult considering the broad host spectrum of *M. chitwoodi* comprising monocotyledonous and dicotyledonous crops and weeds. Crops commonly rotated with potato such as wheat, barley and maize are all hosts for *M. chitwoodi*. The same applies to several vegetables, which could allow *M. chitwoodi* populations to be maintained. There are only a few crops that are known to be non-hosts (see Host section).

For certain crops, cultivars can vary in susceptibility and tolerance towards *M. chitwoodi* (van Riel, 1993), which can help in managing the nematode.

Resistance towards *M. chitwoodi* has been reported from several wild potato species including *S. bulbocastanum*, *S. fendleri*, *S. hougasii* and *S. stenophyllidium* (Janssen *et al.*, 1996; Graebner *et al.*, 2018). Efforts to introgress those resistance genes into *S. tuberosum* are ongoing, but it will take several more years before resistant cultivars are expected to enter the market. If resistant cultivars become available and the resistance is based on a single gene, resistance management will be required to avoid or at least delay the selection of resistance-breaking pathotypes. Strong and so far stable resistance exists in fodder radish providing a good management tool wherever cover crops can be grown (Teklu *et al.*, 2014). Other strategies focus on using plant defence elicitors such as StPep1, secreted by *Bacillus subtilis*, to control *M. chitwoodi* on potato (Zhang & Gleason, 2020).

Cover crops not carrying any resistance can be grown as a trap crop to reduce *M. chitwoodi* populations. Juveniles of *M. chitwoodi* will enter the roots, initiate a feeding site and become sedentary. The so trapped nematodes are then killed by mechanical or chemical destruction of the plants just before egg production starts, i.e. 3-4 weeks after seedlings have emerged. The optimum time point for plant destruction can be calculated according to the degree-days.

Biofumigation might be an additional option for controlling *M. chitwoodi* (Ploeg, 2008).

Where available, fumigants (e.g. 1,3-dichlorpropene, metam sodium) and non-fumigant nematicides (e.g. ethoprophos, fenamiphos, fosthiazate, oxamyl) are used to control *M. chitwoodi*, with fumigant nematicides generally being more effective than non-fumigants (Ingham *et al.*, 2000). Site-specific management practices might help in reducing the negative impact of those nematicides on the environment (King & Taberna, 2013).

Phytosanitary risk

So far, the distribution of *M. chitwoodi* is limited to few countries in the more temperate regions of Europe and North America; However, *M. chitwoodi* may be able to establish in a large proportion of its host area in the EPPO Region. Establishment would depend on climate, management practices (e.g. crop rotation, irrigation) and soil texture. High temperatures and/or dry periods in absence of a host plant are considered the most limiting factors for establishment and development in the South of the EPPO region (EFSA, 2012). *M. chitwoodi* presents a high damage potential to root and tuber crops such as potato, carrot and black salsify, potato being the crop that would be most at risk in the EPPO region. *M. chitwoodi* is considered to represent a greater threat than other *Meloidogyne* species already widespread in the EPPO region, in particular *M. hapla*, with which it often forms mixed populations. Indeed, *M. chitwoodi* is less easily controlled by crop rotation and nematicides, it has a wider host range, it produces more severe tuber symptoms and is tolerant of lower soil temperatures.

PHYTOSANITARY MEASURES

Measures similar to those for other root-knot nematodes would appear relevant, i.e. that rooted host plants for planting (with or without soil), non-host plants for planting with soil attached and plant products with soil attached come from a pest free area, a pest free place of production or are produced under protected cultivation. Alternatively, soil from non-host plants for planting or plant products can be removed. Soil as such can originate from a pest free area or a pest free place of production. Used machinery, equipment, vehicles, and passengers' shoes can be cleaned. Publicity would enhance public awareness about *M. chitwoodi* for travellers.

Specific requirements are recommended in EPPO Standard PM 8/1 *Commodity-specific phytosanitary measures for Potato*

(EPPO, 2017) for seed and ware potatoes to be imported from third countries. In this Standard, seed potato freedom from *M. chitwoodi* can also be guaranteed by testing the seed potatoes after harvest following EPPO Standard PM 3/69 *Meloidogyne chitwoodi* and *M. fallax*: *sampling potato tubers for detection* (EPPO, 2019a). Ware potatoes freedom can also be guaranteed by implementing EPPO Standard PM 9/17 *National regulatory control system for Meloidogyne chitwoodi* and *M. fallax* (EPPO, 2013b). EPPO Standard PM 3/61 details conditions for establishing pest-free areas and pest-free production and distribution systems for quarantine pests of potato (EPPO, 2019b).

Measures to contain or eradicate *M. chitwoodi* and *M. fallax* are described in the national regulatory control system (EPPO, 2013b). The regulatory control system was developed for potato but can be applied to other crops as well, with possible slight modifications depending on the crops.

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Datasheet history

This datasheet was first published in 1997 in the second edition of 'Quarantine Pests for Europe', and revised in 2020. It is now maintained in an electronic format in the EPPO Global Database. The sections on 'Identity', 'Hosts', and 'Geographical distribution' are automatically updated from the database. For other sections, the date of last revision is indicated on the right.

CABI/EPPO (1997) *Quarantine Pests for Europe (2nd edition)*. CABI, Wallingford (GB).



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