

EPPO Datasheet: *Meloidogyne fallax*

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IDENTITY

Preferred name: *Meloidogyne fallax*

Authority: Karssen

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

Common names: false Columbia root-knot nematode

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EPPO Categorization: A2 list

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

EPPO Code: MELGFA



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Notes on taxonomy and nomenclature

Meloidogyne fallax was detected for the first time in 1992 in a field plot experiment 1.5 km north of Baexem (NL), and was initially considered as a deviant *M. chitwoodi* Golden population (Karssen, 1994). On the basis of differences in isozyme patterns, *M. fallax* was proposed as a new race of *M. chitwoodi* (van Meggelen *et al.*, 1994), and named *M. chitwoodi* B-type (Karssen, 1995). As more differences between *M. chitwoodi* and the B-types were discovered, this race status became unacceptable, and *M. fallax* was described as a new species (Karssen, 1996).

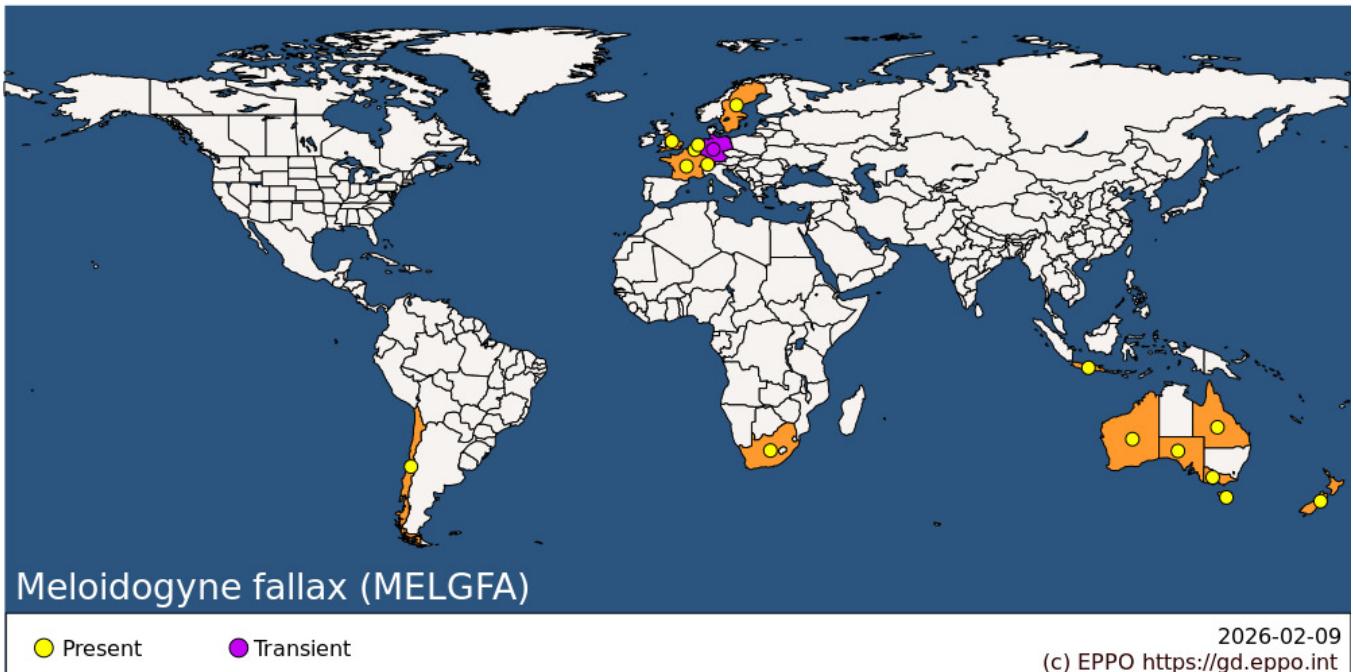
HOSTS

M. fallax was detected on and described from potato (*Solanum tuberosum*). Host-range includes a wide range of dicotyledonous and monocotyledons plants, including weeds, ornamentals, and economically important crops such as carrot (*Daucus carota*), black salsify (*Scorzonera hispanica*) and tomato (*Solanum lycopersicum*). The experimental host range of *M. fallax* mostly overlaps that of *M. chitwoodi*, but differential hosts have been found. For example dwarf beans (*Phaseolus vulgaris*), valerian (*Valeriana officinalis*), maize (*Zea mays*), *Erica cinerea* and *Potentilla fruticosa* are good hosts for *M. chitwoodi* and not for *M. fallax*, while the reverse is the case for *Oenothera glazioviana*, *Phacelia tanacetifolia*, *Hemerocallis* cv. Rajah and *Dicentra spectabilis* (Brinkman *et al.*, 1996). It is expected that many more plant species will be hosts of *M. fallax* than currently known, since this is the case also with other, closely related root knot nematodes.

Host list: *Allium porrum*, *Asparagus officinalis*, *Avena strigosa*, *Beta vulgaris*, *Cichorium intybus*, *Cynara scolymus*, *Daucus carota* subsp. *sativus*, *Fragaria x ananassa*, *Hemerocallis* sp., *Hordeum vulgare*, *Lactuca sativa*, *Lamprocapnos spectabilis*, *Leptinella* sp., *Lolium multiflorum*, *Medicago sativa*, *Oenothera glazioviana*, *Phacelia tanacetifolia*, *Scorzonera hispanica*, *Solanum lycopersicum*, *Solanum nigrum*, *Solanum physalifolium*, *Solanum tuberosum*, *Trifolium repens*, *Triticum aestivum* subsp. *aestivum*

GEOGRAPHICAL DISTRIBUTION

After the first record near Baexem (NL) in 1992, *M. fallax* was recorded on potato at several locations in the southern and south-eastern part of the Netherlands (Karssen, 1996), close to the German and Belgium borders. Within the EPPO region it was detected locally in Belgium, France, Germany, Sweden, Switzerland and the United Kingdom (England). In addition, Topalovi? *et al.* (2017) revealed that a *Meloidogyne* species detected in Ireland in 1965 belongs to *M. fallax*. *M. fallax* has never been reported from the natural environment in Europe. Outside Europe it has been reported from Australia, Chile, New Zealand and South Africa. New Zealand is the only known country where *M. fallax* is widely distributed (North and South Island) and detected in cropping and pasture fields (Rohan *et al.*, 2016), strongly suggesting that it could be the place of origin of this pest.



EPPO Region: Belgium, France (mainland), Germany, Netherlands, Sweden, Switzerland, United Kingdom (England)

Africa: South Africa

Asia: Indonesia (Java)

South America: Chile

Oceania: Australia (Queensland, South Australia, Tasmania, Victoria, Western Australia), New Zealand

BIOLOGY

The life cycles of *M. fallax* and *M. chitwoodi* are, in general, the same with respect to root penetration, gall induction, symptomatology, number of moults, parthenogenetic reproduction and chromosome number: Both *M. chitwoodi* and *M. fallax* usually reproduce by parthenogenesis. They can have one to three generations per year in the Netherlands and produce several hundreds of eggs per female, deposited in an egg sac. These egg sacs allow the eggs to survive under unfavorable conditions (EFSA, 2019). Initial results by van der Beek (1997) indicated that *M. fallax* had a shorter life cycle than *M. chitwoodi* in a virulence study on potato.

Host races, as described for *M. chitwoodi*, have not been detected for *M. fallax* so far. Successful hybridization was not obtained when *M. fallax* and *M. chitwoodi* were crossed in two different experiments; the F1 was viable, but the F2 second-stage juveniles were not viable and showed morphological distortions (van der Beek & Karssen, 1997).

In addition, differences in terms of hatching responses to root diffusate and host age between *M. chitwoodi* and *M. fallax* suggests different survival strategies between these two species (Wesemael *et al.*, 2006).

M. fallax, *M. chitwoodi* and *M. minor* Karssen are closely related, morphologically and at DNA level. Phylogenetically they appear to be in the same distinct clade within the genus *Meloidogyne* (Holterman *et al.*, 2009; Elling, 2013).

DETECTION AND IDENTIFICATION

Symptoms

Above-ground symptoms of heavily infested plants include stunting and yellowing, while below ground galling is typical. The root galls produced by *M. chitwoodi* and *M. fallax* are comparable to those produced by several other

root-knot species, i.e. relatively small galls in general without secondary roots emerging from them (these secondary roots are seen in *M. hapla*). On potato tubers, *M. chitwoodi* and *M. fallax* cause numerous small pimple-like raised areas on the surface (in *M. hapla* these swellings are not evident). Some potato cultivars, although heavily infested, may be free from visible external symptoms, while the internal potato tissue is necrotic and brownish, just below the peel (EPPO, 2016a).

Morphology

Sedentary females are annulated, pearly white and globular to pear-shaped, 400-720 µm long and 250-460 µm wide. The stylet is dorsally curved, 13.9-15.2 µm long, with rounded to ovoid stylet knobs, slightly sloping posteriorly. The non-sedentary males are vermiform, annulated, slightly tapering anteriorly, bluntly rounded posteriorly, 735-1520 µm long and 27-44 µm wide. The stylet is 18.9-20.9 µm long, with large rounded knobs, set off from the shaft. The non-sedentary second-stage juveniles are vermiform, annulated, tapering at both ends, 380-435 µm long, 13.3-16.4 µm wide, with a tail length of 46-56 µm and a hyaline tail part 12.2-15.8 µm in length (Karssen, 1996).

M. fallax is closely related morphologically to *M. chitwoodi*, and this misleading resemblance was the reason for giving the species its name. The most striking differences for males and females are stylet length (longer for *M. fallax*) and stylet knob shape (*M. fallax*: prominent and rounded; *M. chitwoodi*: small and irregular). The second-stage juveniles differ in mean body length, tail length and hyaline tail length (all longer for *M. fallax*). With the scanning electron microscope, it can be observed that the male head of *M. fallax* has an elevated labial disk. Differences exist in the female perineal pattern (*M. fallax* has a relatively higher dorsal arch and thicker striae) (EPPO, 2016a; see also Karssen, 2002).

The species can be reliably distinguished by morphological observation of females, males, and second-stage juveniles in combination with biochemical (isozyme electrophoresis) or molecular (PCR) methods; see EPPO, 2016. To predict the amount of potato tuber damage caused by *M. fallax*, a quantitative DNA-test was developed for soil (Hay *et al.*, 2016).

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 Standards PM 7/119 (EPPO, 2013a) and PM 7/41 *Diagnostic protocol for Meloidogyne chitwoodi and M. fallax* (EPPO, 2016a).

Historically, in order to distinguish *M. fallax* from other *Meloidogyne* spp., molecular methods have been used. Karssen *et al.* (1995) discriminated *M. fallax* and *M. chitwoodi* females by their esterase (EC 3.1.1.1) and malate dehydrogenase (EC 1.1.1.37) isozyme patterns, using the general method of Esbenshade & Triantaphyllou (1985) for identification of female *Meloidogyne* species by isozyme electrophoresis. Additionally, the isozyme glucose 6-phosphate dehydrogenase (EC 1.1.1.49) was used to differentiate the two species (van der Beek & Karssen, 1997). van der Beek *et al.* (1997) and Tastet *et al.* (1999) used mini two-dimensional gel electrophoresis to study the total soluble protein patterns of *M. hapla*, *M. chitwoodi* and *M. fallax*, and confirmed these species to be distinct biological groups. An overwhelming number of molecular tests has been developed to identify *M. fallax* from soil, root or tubers and to separate it from related species such as *M. chitwoodi*, including PCR (Peterson & Vrain, 1996, Peterson *et al.*, 1997; Wishart *et al.*, 2002), PCR RFLP (Zijlstra *et al.* 1995, Zijlstra, 1997) AFLP (v.d. Beek *et al.*, 1998; Fargette *et al.*, 2005), SCAR (Zijlstra, 2000; Fourie *et al.*, 2001), real time TaqMan PCR (Zijlstra & v. Hoof, 2006; de Haan *et al.*, 2014), RAPD (Adam *et al.*, 2007), satDNA (Castagnone-Sereno *et al.*, 1999; Castagnone-Sereno, 2000; Mestrovich *et al.*, 2009 & 2013), LAMP (Zhang & Gleason, 2019), HRMC (Holterman *et al.*, 2012), barcoding (Hodgetts *et al.*, 2016, EPPO, 2016b). A serological test was also developed to separate *M. fallax* from *M. chitwoodi* and other root-knot nematodes (Tastet *et al.*, 2001). Only a selection of the above-mentioned tests are recommended for identification (see EPPO, 2016a).

PATHWAYS FOR MOVEMENT

M. fallax 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. fallax* into a new area is through the movement of infested or contaminated planting material. Infested host plants or host products such as bulbs or tubers can easily transport the nematode. The movement of non-host plants for planting (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. fallax* could also result in spread (EPPO, 2013b). Soil as such is also a possible pathway. Infective juveniles of this genus have been known to persist for more than one year in the absence of host plants. Nematode movement can also be facilitated by contaminated irrigation water.

PEST SIGNIFICANCE

Economic impact

In trials, *M. fallax* caused the same symptoms on potato tubers, black salsify and carrots as *M. chitwoodi*, i.e. external galling and internal necrosis just below the skin (Brinkman *et al.*, 1996; van Riel & Goossens, 1996). The reported natural outbreaks of *M. fallax* on potato showed these external symptoms (Karssen, 1996). Goossens (1995) reported infected *Asparagus officinalis* and several ornamentals with root-knots in an experimental field with an infestation of *M. fallax*. *M. fallax* sometimes occurs in mixed infestations with *M. chitwoodi* (Wesemael *et al.*, 2006).

Meloidogyne fallax mainly induces quality losses caused by cosmetic damage on black salsify, leek, carrot and potato. If the level of infection is high a complete rejection of these crops is possible. So far, this nematode has a limited damaging effect on other known host crops (EFSA, 2012).

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

Control

There is no direct practical experience of the control of *M. fallax*. Research on *M. fallax* in the Netherlands has focused on host suitability, damage thresholds, effect of fallow, the use of green manure crops and time of sowing. The first results indicate that fallow for one year reduced the population by more than 95%, but this reduction was not sufficient to ensure that subsequent crops met quality standards. There was less damage in sugar beet and carrot when these crops were sown later in spring. Farmers are advised to be careful when growing green-manure crops on infested fields, because some species are suitable hosts for *M. fallax*. *Phaseolus vulgaris* was the only tested crop with no reproduction of *M. fallax*, while maize and cereals were poor hosts (Brommer, 1996). Several green manures were tested, and no reproduction of *M. fallax* was found on *Eruca Sativa* cv Trio, *Tagetus patula* and *Borago* spp., while *Raphanus sativus* was a poor host. *Avena strigosa* turned out to be a very good host (Visser & Molendijk, 2015).

Janssen *et al.* (1996) tested several wild tuber-bearing *Solanum* species, to determine the level of resistance to *M. hapla*, *M. chitwoodi* and *M. fallax*. High resistance to *M. chitwoodi* and *M. fallax* was observed in genotypes of *S. bulbocastanum*, *S. hougasii*, *S. cardiophyllum*, *S. fendleri* and *S. brachistotrichum*. Differential resistance between *M. chitwoodi* and *M. fallax* was observed in *S. chacoense*, *S. stoloniferum* and *S. gourlayi*. Resistance to *M. fallax* was also found in *Solanum sparsipilum* (Kouassi *et al.*, 2004) and the resistance gene was studied (Kouassi *et al.*, 2006). By crossing wild tuber bearing *Solanum* species with *Solanum tuberosum*, successful introgression of resistance to *M. fallax* and *M. chitwoodi* into potato was obtained (Janssen *et al.*, 1997).

In addition, useful resistance against *M. fallax* was found in sea beet (*Beta maritima*) (Yu *et al.*, 1999) and used to develop a resistant sugar beet line (*Beta vulgaris*) (Yu, 2001).

Wesemael & Moens (2012) tested ten common bean (*Phaseolus vulgaris*) cultivars and noted that all these cultivars were non-hosts or poor hosts for *M. fallax*.

An interesting potential control method consists of using the hyper-parasitic bacterium *Pasteuria* spp. So far three different species of *Pasteuria* are reported to be able to parasitize *M. fallax*: *P. penetrans*, *P. nishizawae* and *P. hartismeri* (Wishart *et al.*, 2004; Bishop *et al.*, 2007).

Phytosanitary risk

Because *M. fallax* occurs in crops and situations which are similar to those for *M. chitwoodi*, and the two species are closely related and difficult to distinguish, *M. fallax* presents a phytosanitary risk similar to that of *M. chitwoodi* (EFSA, 2012). *M. fallax* may be able to establish in a large proportion of its host area but may only cause significant damage in certain areas and under certain conditions, causing complete crop rejection (e.g. on potato, carrot and/or black salsify). Soils with a coarse texture such as sandy and sandy-loam soils have a higher probability of being contaminated. Narrow rotation or rotation with alternative hosts facilitates a rapid build-up of population levels and therefore increases the risk for establishment of *M. chitwoodi* and *M. fallax* in a particular field. As observed since 1992, *M. fallax* is expected to spread slowly (EFSA, 2012).

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 machineries, equipment, vehicles, and passengers' shoes can be cleaned. Publicity would allow to enhance public awareness on *M. fallax* when travelling.

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. fallax* 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).

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