

Medicinal Plant Diseases Caused by Nematodes

Faezehossadat Abtahi and Mansoureh Bakooie

Abstract The agents that cause infectious disease in plants are pathogenic microorganisms, such as viruses, bacteria, fungi, protozoa, and nematodes. Several hundred species of nematodes, however, are known to feed on living plants, obtaining their food with spears or stylets and causing a variety of plant diseases worldwide. Almost all plant pathogenic nematodes live part of their lives in the soil. Many live freely in the soil, feeding superficially on roots and underground stems, and in all, even in the specialized sedentary parasites, the eggs, the preparasitic juvenile stages, and the males are found in the soil for all or part of their lives. Nematodes occur in greatest abundance in the top 15 to 30 centimeters of soil. A few nematodes that attack the aboveground parts of plants not only spread through the soil as described earlier, but they are also splashed to the plants by falling rain or overhead watering. All plant parasitic nematodes belong to the phylum *Nematoda*. In this chapter, considering the importance of plant diseases caused by nematodes, we review some of the most important diseases of some of the medicinal plants.

Keywords Medicinal Plants · Pathogenic microorganisms · Loss Nematodes

Introduction

Nematodes belong to the kingdom *Animalia*. Nematodes are wormlike in appearance but quite distinct taxonomically from the true worms. Several hundred species are known to feed on living plants, obtaining their food with spears or stylets and

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causing a variety of plant diseases worldwide. Almost all plant pathogenic nematodes live part of their lives in the soil. Soil temperature, moisture, and aeration affect survival and movement of nematodes in the soil. Nematodes occur in greatest abundance in the top 15–30 cm of soil. The overall distance traveled by a nematode probably does not exceed a few meters per season. Nematode infections of plants result in the appearance of symptoms on roots as well as on the aboveground parts of plants. Root symptoms may appear as root lesions, root knots or root galls, excessive root branching, injured root tips. The root symptoms are usually accompanied by symptoms in the aboveground parts of plants, appearing primarily as reduced growth, symptoms of nutrient deficiencies such as yellowing of foliage, excessive wilting in hot or dry weather, reduced yields, and poor quality of products. All plant parasitic nematodes belong to the phylum *Nematoda*. Most of the important parasitic genera belong to the order *Tylenchida*, but a few belong to the order *Dorylaimida*.

Scientific name: *Achillea millefolium* L.

Common name: Yarrow

Mesoanguina millefolii (Low 1874) Chizhov and Subbotin (1985) induce small galls on the leaves of yarrow (Goodey 1938; Hooper and Doncaster 1972; Evtushenko et al. 1994). The milfoil cyst nematode, *Heterodera millefolii*, and yarrow cyst nematode, *Heterodera achilleae* were reported from this plant in Russia and Yugoslavia, respectively. Host tests at Sarajevo; Yugoslavi showed that yarrow, *Achillea millefolium* L. was heavily attacked (Fig. 1) (Golden and Klindic 1973). *Meloidogyne* sp., *Helicotylenchus* sp., *Xiphinema* sp. and Dorylaimid were reported on yarrow in Isfahan, Iran (Nasresfahani et al. 2015).

Scientific name: *Atropa belladonna* L.

Common name: Belladonna, Deadly nightshade

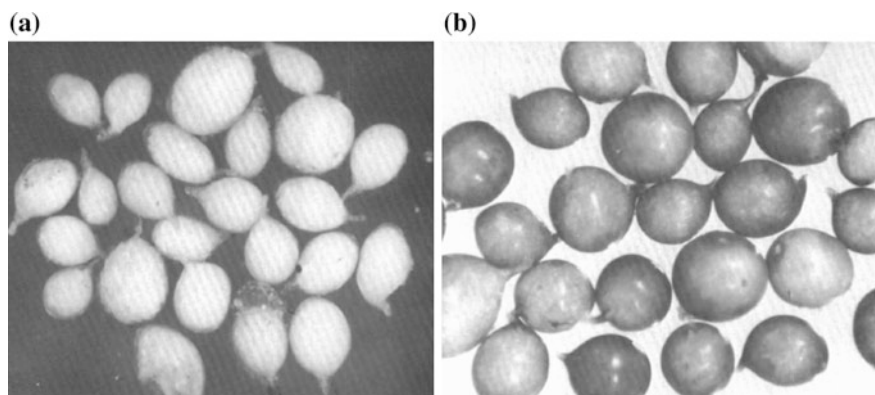


Fig. 1 Phomicrographs of whole specimens of *Heterodera achilleae* **a** White females (note egg mass attached to one specimen), **b** Cysts $\times 30$ (after Golden and Klindic 1973)

Longidorus spp. was identified on *Atropa belladonna* in Uttar Pradesh, India. Four larvae of this parasitic nematode were collected from soil sample of 5–30 cm depths (Rashid et al. 1973).

Scientific name: *Berberis vulgaris* L. var. *sperma*

Common name: Berberry, Common berberry

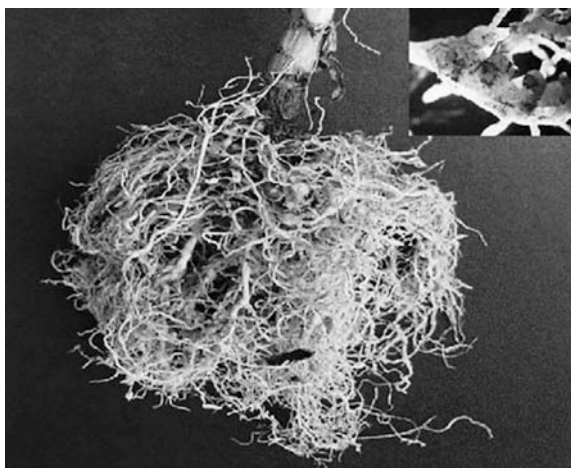
Plant parasitic nematodes; *Merlinius acuminatus* (Minagawa 1985; Brzeski 1991, *Geocenamus dobroticus* (Budurova et al. 1996), *Paratylenchus vandenbrandei* (De Grisse 1962), *Criconemoides morgensis* (Hofmanner and Menzel 1914) and *Boleodorus* spp. (*B. typicus* (Husain and Khan 1968), *B. impar* (Khan and Basir 1964), *B. volutus* (Lima and Siddiqi 1963) and *B. thylactus* (Thorne 1941)) were collected from the rhizosphere of *Berberis vulgaris* crop in the South Khorasan Province of Iran. The male nematodes was founded only in *B. typicus* species (Alvani et al. 2013, 2016). Two species *Irantylenchus vicinus* and *Neopsilenchus magnidens* were reported on this plant, also (Alvani et al. 2015).

Scientific name: *Calendula officinalis* L.

Common name: Marigold

Meloidogyne incognita (Kofoid and White) Chitwood race 1 (Magbool et al. 1985) reported on this flower plant from Pakistan. Moreover, the root system of *Calendula officinalis* showed clear symptoms of attack by root-knot nematode *Meloidogyne incognita* in Italy (Fig. 2). However, the low degree of infestation and tolerable damage is related with the cultivation period of this plant from the end of September to the beginning of March. Therefore, a treatment with non-volatile nematicide has been recommended for nematode control (Russo et al. 2008). *Meloidogyne incognita*, *M. javanica* and *Rotylenchus reniformis* were also recorded on marigold in India (Bhat et al. 2014). In New Zealand *Meloidogyne hapla* recognized on marigold (Dale 1971). It is recently reported that the peach root knot

Fig. 2 Roots of *Calendula officinalis* infested by *Meloidogyne incognita* (After Russo et al. 2008)



nematode *Meloidogyne floridensis* (Handoo et al. 2004) in addition to peach, infects many important crops including *Calendula officinalis* cv. Oktoberfest (Brito et al. 2015). *Meloidogyne* sp., *Helicotylenchus* sp., *Xiphinema* sp. and *Ditylenchus* sp. were collected on marigold in Isfahan, Iran (Nasresfahani et al. 2015). *Aphelenchoides besseyi* and *A. ritzemabosi* were detected on *Calendula officinalis* L. (Sanchez-Monge et al. 2015). In South Africa, *Hemicyclophora litorea* Van den Berg found in the rhizosphere of wild calendulas (Van Den Berg 1987) (Fig. 2).

Scientific name: *Carum carvi* L.

Common name: Caraway

Meloidogyne trifoliophila Bernard and Eisenback (Bernard and Eisenback 1997) produced numerous galls on caraway in greenhouse experiment and 50 to 75% of the root system not functioning (Bernard and Jennings 1997).

Scientific name: *Cassia angustifolia* Vahl.

Common name: Senna, Alexandria senna

The infection of root-knot nematode, *Meloidogyne incognita* on senna was recorded. The management of this parasite by different bioagents, organic amendments and humic acid treatments showed that the use of plant growth promoting *Rhizobacterium*, *Pseudomonas fluorescens* as soil application has the lowest nematode population accompanied with highest economic yield (Ramakrishnan and Senthilkumar 2009).

Scientific name: *Catharanthus roseus* L.

Common name: Periwinkle, Madagascar Periwinkle

The results of the host suitability investigations in greenhouse condition were illustrated that Madagascar Periwinkle cultivars; Carpet Dawn, Cooler Grape, Little Blanche, Little Delicata and Polka Dot, ranked slightly susceptible to *M. incognita* race 3 (Walker et al. 1994) and cultivars; Blush Cooler, Little Bright Eyes, Little Mixed Colors and Peppermint rated as a generally poor hosts of *M. incognita* race 1 and *M. javanica* (McSorley and Frederick 1994, 2001). The identification of nematodes collected from Narendrapur medicinal plants garden revealed that *Catharanthus roseus* infected with the plant parasitic nematode, *Hoplolaimus* sp (Haldar and Gupta 2015). This medicinal species was introduced as one of the hosts of the rice-knot nematode *M. graminicola* (Golden and Birchfield 1965; MacGowan and Langdon 1989) and *Pratylenchus roseus* (Zarina and Maqbool 1998; Castillo and Vovlas 2007).

Scientific name: *Crocus sativus* L.

Common name: Saffron

Plant parasitic nematodes, *Aphelenchoides subtenuis* (Cobb 1926; Steiner and Buhner 1932; Koliopanos and Kalyviotis-Gazelas 1979; Decker 1989; Southey 1993; Ortuno and Oros 2002; McCuiston et al. 2007), *Pratylenchus penetrans* and *P. pratensis* (Metcalf 1903; Schenk 1970), *Ditylenchus destructor* (Ortuno and Oros 2002), *Psilenchus hilarulus* (Alvani et al. 2015a), *Tylenchus* sp.,

Hirschmaniella sp., *Psilenchus* sp., *Pratylenchus* sp. and *Helicotylenchus chishtii* (Sheikh et al. 2014), *Amplimerlinius icarus*, *A. macrurus*, *A. socialis*, *Aphelenchoides asterocaudatus*, *A. besseyi*, *A. curiolis*, *Criconemoides deccapiens*, *Ditylenchus dipsaci*, *D. myceliophagus*, *Helicotylenchus crassatus*, *H. exallus*, *Merlinius bavaricus*, *M. brevidens*, *M. graminicola*, *M. microdorus*, *M. nanus*, *M. pseudobavaricus*, *Paratylenchus coronatus*, *Pratylenchus coffeae*, *P. loosi*, *P. penetrans*, *P. thornei*, *Psilenchus elegans*, *P. minor*, *Tylenchorhynchus brassicae*, *Tylenchus parvus*, *Geocenamus squamatus*, *G. tenuidens*, and *Filenchus pratensis*, *F. hamatus* (Mahdikhani and Alvani 2013), *Pratylenchus crenatus* (Kasimova and Atakishieva 1980), *Aerotylenchus safroni* (Fotedar and Handoo 1977) have been identified in *C. sativus*.

Scientific name: *Cuminum cyminum* L.

Common name: Cumin

Occurrence of root-knot nematodes (*Meloidogyne* spp.) on this crop were reported in India (Shah and Patel 1979; Midha and Trivedi 1989).

Scientific name: *Curcuma longa* L.

Common name: Turmeric, Indian saffron, Yellow ginger

The different plant parasitic nematodes like *Meloidogyne* sp., *Rotylenchulus reniformis*, *Helicotylenchus multicinctus*, *Hoplolaimus seinhorstii*, *H. columbus*, *H. indicus*, *Tylenchorhynchus martini*, *Radopholus similis*, *Pratylenchus delattrei*, *P. coffeae*, *Calloosia* sp., *Tylenchus* sp., *Aphelenchus* sp., *Criconemoides ornatus*, *Longidorus elongidorus* and *Xiphinema elongatum* were recorded from the rhizosphere of turmeric of which *Meloidogyne* sp., *Radopholus similis* and *Pratylenchus coffeae* are of the economic important and caused yield losses (Ayyar 1926; Nirula and Kumar 1963; Nadakal and Thomas 1964; Koshy and Sosamma 1975; Vilsoni et al. 1976; Sosamma et al. 1979; Venkitesan and Charles 1980; Bhardwaj and Hogger 1984; Bai et al. 1995; Ray et al. 1995; Poornima and Sivagami 1998, 1999; Haidar et al. 1998; Koshy et al. 2005; Udo and Nwagwu 2007; Idorenyin and Ugwuoke 2010; Aminu-Taiwo et al. 2015). The results of root-knot nematode management experiment in turmeric was indicated that the soil solarization and the organic soil amendment with poultry manure were founded the effective treatment in controlling disease (Patel et al. 2008; Idorenyin and Ugwuoke 2010). The results of the resistant screening revealed that several cultivars and accessions of this crop were resistant to root-knot nematode (Sasser et al. 1984; Gunasekharan et al. 1987; Mani et al. 1987; Eapen et al. 1999; Mohanta et al. 2015; Prasath et al. 2016).

Scientific name: *Datura stramonium* L.

Common name: Thorn apple, Jimson weed

Datuta stramonium was recorded as a good weed host of *Ditylenchus destructor* Thorne in peanut fields in South Africa (Waele et al. 1990) and of *Meloidogyne incognita*, *M. javanica* and *M. arenaria* in Khorasan Province (Iran) and South Carolina (Tedford and Fortum 1988; Gharabadiyan et al. 2012). *M. ethiopica* (Whitehead 1968) was also recognized on *D. stramonium* (O'Bannon 1975).

Scientific name: *Digitalis purpurea* L.

Common name: Foxglove, Common foxglove, *Digitalis*

Paratylenchus spp. (Rashid et al. 1973) and *Pratylenchus penetrans* (Seinhorst 1998) were reported on *Digitalis purpurea*.

Scientific name: *Foeniculum vulgare* Mill

Common name: Sweet fennel, Common fennel

Root-knot nematode is a common problem in fennel (Walker 1995; Patel et al. 1995; Park et al. 2007; Ibrahim and Mokbel 2009; Khare et al. 2014; Nasresfahani et al. 2015; Kumar et al. 2016). This parasite can be managed by the application of oil cakes like neem cake (1000 kg/ha) + phorate (1 kg/ha) or 1000 kg castor cake + 1 kg phorate (Patel et al. 2005) and soil solarization with 25 μ LLDPE film and rabbing with castor husk at 7 kg/m² (Patel et al. 2002). The other plant parasitic nematodes, *Aphelenchoides siddiqii* in Sudan (Fortuner 1970) and *Helicotylenchus* sp., *Xiphinema* sp., *Tylenchus* sp. and *Tylenchorhynchus* sp. in Iran (Nasresfahani et al. 2015) are described from *Foeniculum vulgare* Mill.

Scientific name: *Glycyrrhiza glabra* L. var. *glabra*

Common name: Licorice, liquorice

Aphelenchus avenae and *Pratylenchus* spp. infections were identified on the imported rhizomes of *Glycyrrhiza glabra* from Italy, Polans and Pakistan into New Dehli, India (Mathur et al. 1980).

Scientific name: *Humulus lupulus* L.

Common name: Hops, Common hop

The important plant parasitic nematodes including *Ditylenchus dipsaci*, *D. destructor*, *Bitylenchus dubius*, *Merlinius brevidens*, *Rotylenchus robustus*, *Helicotylenchus canadensis*, *H. digonicus*, *H. labiatus*, *Pratylenchus penetrans*, *P. pratensis*, *P. neglectus*, *P. thornei*, *Paratylenchus bukowinensis*, *Geocenamus* sp., *Trichodorus* sp., *Criconema* sp., *Xenocriconemella* sp., *Mesocriconema* sp., *Longidorus elongates*, *Xiphinema diversicaudatum* (plant virus-vectore nematodes), *Heterodera humuli* (cyst nematode) and *Meloidogyne* spp. (root-knot nematode) were reported from hop plant in India, USA, Czechslovakia, Africa, New Zealand, Australia, Belgium, Canada, England, Holland (Voigt 1894; Percival 1895; Šály and Kříž 1961; Maggenti 1962; Wasilewska 1979; Foot and Wood 1982; Esser 1985; Hogger 1988; McNamara and Eppler 1989; Malan et al. 1991; Hay and Close 1992; Yeates and Wouts 1992; Lopez-Robles 1995; Mende and McNamara 1995a, b; Eppler 1999; Hafez et al. 1999; Reis et al. 1986; Hay and Pethybridge 2003; Hanel 2003, 2010; Liskova and Renco 2007; Grasswitz and James 2008; Mahaffee et al. 2009; Hafez et al. 2010; Renco et al. 2010, 2011). For cyst-forming nematode management has been recommended to prevent the transfer of the nematode to younger plants, washing or cleansing the hop cones and agricultural tools to prevent the possible transfer of adhering cysts and plant stock be taken from healthy specimens (Decker 1981).

Scientific name: *Hyoscyamus niger* L.

Common name: Henbane, Hyoscyamus

It is known that two species *Meloidogyne incognita* and *M. javanica* attacks to *Hyoscyamus niger* and cause agent of the significant reduction in different plant characters (Haseeb and Pandey 1989; Janardhanan 2002). The other parasitic nematodes; *Hoplolaimus* sp., *Helicotylenchus* sp., *Tylenchorhynchus vulgaris*, *Pratylenchus thornei*, *Rotylenchulus reniformis*, *Xiphinema* sp., *Longidorus* sp. and *Trichodorus* sp. were also isolated from rhizosphere of this plant (Southey 1970; Akhtar et al. 2000). The protecting effects of three vesicular-arbuscular mycorrhizal (VAM) fungi against the root-knot nematode infection in *Hyoscyamus niger* indicated that *Meloidogyne incognita* populations in both soil and roots decreased in pot experiments and thus the inoculation of VAM fungi was recommend as a wise option instead of nematicides for reducing root-knot diseases in henbane plant (Pandey et al. 1999).

Scientific name: *Levisticum officinale* W.D.J. Koch

Common name: Lovage

The migratory endoparasitic nematodes *Zygotylenchus guevarai* and *Pratylenchus sudanensis* were collected from lovage farm at Dasht-e-Room, Boyer-Ahmad, Iran (Ansari et al. 2016).

Scientific name: *Matricaria chamomilla* L.

Common name: German chamomile, True chamomile, Common chamomile

The stunt nematode; *Tylenchorhynchus* spp., root lesion nematode; *Pratylenchus* spp. and root-knot nematode; *Meloidogyne* spp. were the major parasitic nematodes on chamomile showed an infection of 81.9, 56 and 45.5%, respectively (Ismail et al. 2002).

Scientific name: *Mentha piperita* L.

Common name: Pepper mint, Black mint, Candy mint

Information was showed the occurrence and distribution of phytoparasitic nematodes such as *Helicotylenchus digonicus*, *H. pseudorobustus*, *Mesocriconema ornatum*, *Paratylenchus projectus*, *P. tenuicaudatus*, *Tylenchorhynchus clarus*, *Pratylenchus coffeae*, *Rotylenchulus reniformis*, *Xiphinema* sp., *Longidorus elongates*, *Pratylenchus thornei*, *P. penetrans*, *Amplimerlinius gelobigerus*, *Criconema mutabil*, *Criconemella xenoplax*, *Meloidogyne* spp. from India, Iran, Egypt, Pakistan, USA (Bergeson and Green 1979; Haseeb 1994; Haseeb and Shukla 1996; Merrifield and Ingham 1996; Shukla et al. 1998; Hashemi and Akbarinia 2009; Hafez et al. 2010; Khanzada et al. 2012; Ibrahim and Handoo 2016) on pepper mint influence the plant growth, oil yield, physiological and biochemical changes in plant. The survey of the chemical control of *Longidorus elongates* with nonvolatile nematicides was indicated that foliar sprays of oxamyl and later with granular incorporation of aldicarb and oxamyl in soil resulted the greatest yield response (Pinkerton and Jensen 1983).

Scientific name: *Nigella sativa* L.

Common name: Black cumin, Black seed

Meloidogyne incognita was recorded on *Nigella sativa* (Haidar et al. 2001).

Scientific name: *Panax ginseng* L.

Common name: Chinese ginseng, Korean ginseng, Oriental ginseng

The several studies were revealed presence of plant parasitic nematode namely, *Criconemoides morgensis*, *Ditylenchus destructor*, *Helicotylenchus dihystra*, *Meloidogyne incognita*, *M. hapla*, *Paratylenchus lepidus*, *Pratylenchus penetrans*, *P. subpenetrans*, *Psilenchus hilarulus*, *Trichodorus similis*, *Tylenchorhynchus claytoni*, *Xiphinema americanum* on ginseng (Choi 1976; Ahn et al. 1983; Janardhanan 2002; Chung et al. 2004; Kim et al. 2006). *Meloidogyne* spp. induce root galls, *Ditylenchus destructor* attacks tubers and rhizomes, stem-like underground parts, causing the formation of necrosis. *D. destructor* causing root rot disease of ginseng, infected roots exhibit small discolored spots. In heavy attacks, the epidermis becomes grayish-black, abnormally thin, dry and cracked; underlying tissues are spongy and brownish, forming lumpy masses. *P. penetrans* is a migratory endoparasite of roots, its infection make fine reddish-brown lesions on rootlets. The typical symptoms resulted of *P. subpenetrans* observed took the form of lesions on the main root of 1-year-old seedlings, the lesions being sunken and the roots constricted in places. Sometimes, severe constrictions occurred at several sites on a single root, producing a bead-like appearance. The lower portion of severely rotted roots was sometimes missing. The control practices for the important nematodes have been suggested. If root lesion nematode populations exceed 100 per 100 cc of soil, when sampled in late summer, soil fumigation prior to planting should be treated. In fields infected by *Ditylenchus destructor*, the soil fumigation by cylon and treated with ethoprop or triazophos suppressed the nematode populations (Ohh et al. 1983, 1986; Chung et al. 2004; Kim et al. 2006).

Scientific name: *Papaver somniferum* L.

Common name: Opium poppy, Common poppy

Different plant parasitic nematodes; *Basirolaimus saccharis*, *Meloidogyne incognita*, *Boleodorus thylactus*, *Ditylenchus anchilisposomus*, *D. dipsaci*, *Filenchus filiformis*, *Helicotylenchus digonicus*, *Pratylenchus alkani*, *P. coffeae*, *P. pratensis*, *Pratylenchoides conincki*, *Tylenchorhynchus latus*, *T. striatus*, *Zygotylenchus guevarai* were associated with poppy crop (*Papaver somniferum* L.) (Schmitt and Lipscomb 1975; Shamsi 1979; Rakesh et al. 1999; Akgul and Okten 2001).

Scientific name: *Pimpinella anisum* L.

Common name: Anise, Anise seed, Aniseed, Sweet cumin

In the survey carried out in anise growing areas in Burdur province, Turkey 15 species; *Sakia propora*, *Irantylenchus clavidorus*, *Boleodorus mirus*, *Tylenchorhynchus annulatus*, *Bitylenchus maximus*, *Quinisulcius acutus*, *Negelus affinis*, *Hoplolaimus geleatus*, *Helicotylenchus dihystra*, *Pratylenchus zaeae*,

P. alkani, *Meloidogyne arenaria*, *Loofia thienemanni*, *Ditylenchus dipsaci*, *Safranema anchilispesoma* of the families Tylenchidae, Dolichodoridae, Hoplolaimidae, Pratylenchidae, Meloidogynidae, Hemicycliophoridae and Anguinidae were isolated (Kepenekci 2003).

Scientific name: *Plantago ovata* Forssk.

Common name: Plantago, Blond psyllium, Isabgol

Root-knot nematode, *Meloidogyne incognita* was significantly reduced in all growth parameters viz., root shoot length, fresh and dry root-shoot weights, number of spikes/plant and seed weight/plant on plantago (Kumar and Haseeb 2011).

Scientific name: *Rosmarinus officinalis* L.

Common name: Rosemary

Plant parasitic nematodes; *Helicotylenchus pseudorobustus*, *H. californicus*, *H. indicus*, *H. nigeriensis*, *Merlinus microdorus*, *M. indicus*, *Boleodorus thylactus*, *Psilenchus minor*, *P. hilarulus* from Iran (Mahdikhani and Mokaram 2011) and different root-knot nematodes; *Meloidogyne* spp. from Brazil and Iran (Pauletti and Echeverrigaray 2002; Nasresfahani et al. 2015), *M. incognita* race 3 (Walker 1995) and *M. javanica* from Israel (Gamliel and Yarden 1998) were collected on rosemary.

Scientific name: *Valeriana officinalis* L.

Common name: Valerian

The root lesion nematode; *Pratylenchus pratensis* from Germany (Pavlyuk 1972), migratory endoparasite nematode; *Ditylenchus* sp. from Russia (Sturhan and Brzeski 1991) and *Meloidogyne* sp., *Helicotylenchus* sp., *Tylenchus* sp. and *Tylenchorhynchus* sp. (Nasresfahani et al. 2015) were reported on valerian.

Scientific name: *Vinca minor* L.

Common name: Periwinkle, Lesser periwinkle, Small periwinkle

Meloidogyne ardenensis (Susana and Santos 1967), *M. hapla* (Walker 1965; Piron 1975), *Heterodera* sp. (Walker 1965) and *Xiphinema americanum* (Epstein and Barker 1966) were reported from periwinkle.

Scientific name: *Thymus vulgaris* L.

Common name: thyme, garden thyme

Two species, *Criconemella antipolitana* and *Geocenamus brevidens* were identified on thyme in Iran (Hashemi and Akbarinia 2009).

There were no reports about the medicinal plants susceptibility of *Angelica archangelica* L. (angelica, garden angelica), *Artemisia dracunculus* L. (tarragon), *Althea officinalis* L. (marsh mallow), *Bunium persicum* (Boiss.) Fedtsch. (black caraway) to plant parasitic nematodes in the literature.

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