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NEMATODE-WILD PLANT INTERACTIONS AND THEIR IMPLICATION IN NEMATODE MANAGEMENT

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Covarelli G., Pannacci E., Greco N. – Nematode-wild plant interactions and their implication in nematode management.

Many species of plant parasitic nematodes are known to have hundreds of host plant species, both cultivated and wild. In the absence of host crop plants, wild plants often are good alternative hosts for the nematodes of which they not only ensure survival but also soil population densities larger than the tolerance levels for different host crop plants. This is known to occur for a few cyst nematodes, such as the sugar beet cyst nematode, *Heterodera schachtii*, in the presence of several crucifers and chenopodiaceous wild plants, and for many other nematodes known to have rather large host ranges. These include the bulb and stem nematode, *Ditylenchus dipsaci*, the root-knot nematodes, *Meloidogyne* spp., and the lesion nematodes, *Pratylenchus* spp., which have as host plants many wild plants infesting crops during a period of the year suitable for the nematodes. The control of infesting weeds not only improves the growth of the cultivated host plants because of absence of competitors, but also prevents increase of soil nematode densities in their absence and, therefore, may serve as an effective and useful control option of nematodes, especially suggested for inclusion in integrated pest management programmes based on control methods alternative to synthetic nematicides.

KEY WORDS: control, nematodes, wild plants, host ranges, survival.

INTRODUCTION

Plant parasitic nematodes are among the most severe pests of crop plants of which they drastically reduce growth and yield (SASSER and FRECKMAN, 1987). The extent of damage these pathogens cause to plants depends upon the species and its soil population density and the species of the host crop plant (Greco and DI VITO, 2009). Some groups of nematodes, such as cyst, root-knot and bulb and stem nematodes, can be very destructive if no control measure is adopted. Nematodes are adapted to a variety of environmental conditions and in general their life cycle is synchronised with that of the main host plant. In some particular situations, such as in rice growing areas, most of the nematode damaging rice can also reproduce on most of the weeds associated to this host crop (BRIDGE *et al.*, 2005; MEDINA *et al.*, 2009). While some nematode genera include species having rather narrow host ranges (*Heterodera*, *Globodera*), others (*Aphelenchoides*, *Ditylenchus*, *Meloidogyne*, *Pratylenchus*) includes species whose host ranges comprise hundreds of plant species. However, investigations on nematodes have been conducted with reference to their most susceptible crop plant hosts and only in a few cases wild plants have been the subject of the nematode-plant interaction studies. Therefore, the available information on wild plants hosts of nematodes have been obtained mostly for chances and, therefore, is far from being sufficient. Nevertheless, for some of the most important species of nematodes the available information can be considered satisfactory. In general, the interactions between nematodes-wild plants are similar to those between nematodes and cultivated host plants. However, wild plants may not show symptoms of nematode attacks on aerial parts and may be rather tolerant to these parasites.

WILD PLANTS HOSTS FOR SOME NEMATODES OF IMPORTANCE IN ITALY

CYST FORMING NEMATODES

These nematodes are generally known as having rather narrow host ranges although some of them can reproduce on many plant species.

Globodera spp.

In Italy three species of *Globodera* are present. They are *G. tabacum tabacum* (Lownsbery *et* Lownsbery) Skarbilovich, *G. rostochiensis* (Wollenweber) Skarbilovich and *G. pallida* Stone. Of them *G. t. tabacum* has been reported from the Campania region infesting eggplant (AMBROGIONI and D'ERRICO, 1996). It causes severe yield loss of tobacco in USA and can infect also tomato and pepper. However, information on wild plants host for this nematodes is lacking.

The other two species, known as potato cyst nematodes, are widespread in all major potato growing areas of Italy, with *G. pallida* mainly in southern regions, both causing severe yield loss to potato. To some extent, they can also reproduce on tomato and eggplant (SUBBOTIN *et al.*, 2010a). A recent review (SULLIVAN *et al.*, 2007) lists 170 plant species as potential hosts for these nematodes. Most of them are wild plants with the majority belonging to the genus *Solanum* and only a few to the genera *Datura*, *Hyoscyamus*, *Lycopersicon*, *Physalis*, *Physoclaina*, *Salpiglossis*, and *Saracha*, all of the family Solanaceae. However, these plants are not common in Italy and, therefore, there is little or no chance that in the absence of the potato crop both cyst nematodes can survive and reproduce on wilt plant species present in Italy.

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Heterodera spp.

The sugar beet cyst nematode, *Heterodera schachtii*, is widespread in North America and Europe causing damage to sugar beet and several crucifer crops. It is also present in several Italian regions and probably is the cyst nematode having the largest host range. STEELE (1965) listed 206 plant species on which specimens of the nematodes were found. However, the most important host plants are within the families Chenopodiaceae and Cruciferae (STEELE, 1965; SUBBOTIN *et al.*, 2010b), including wild plants. An investigation conducted in the Fucino area (province of L'Aquila, central Italy), where the nematode is spread, revealed that in sugar beet fields, *Amaranthus* sp., several species of *Chenopodium*, *Artemisia* spp., *Calepina* spp., *Capsella bursa-pastoris*, *Diplotaxis erucoides*, *Raphanus raphanistrum* and *Mercurialis officinalis* were infested by the nematode. Moreover, in a greenhouse pot study, *Atriplex* spp., *Capsella bursa-pastoris* and *Raphanus raphanistrum* increased the nematode population similarly to host crop plants (GRECO and BRANDONISIO, 1982). These three wild plants are common in Italy.

The cereal cyst nematode, *Heterodera avenae* Woll., is also spread in Italy, the Mediterranean region and elsewhere and causes severe damage to wheat, barley and oats in rather sandy soil but not in rather clay soil. The nematode can reproduce to some extent on wild winter species of Poaceae and thus perpetuate the nematode in the absence of the major host crops. *Heterodera filipjevi* Madzhidov, another cereal cyst nematode, has been reported from the former USSR countries, south Italy and many countries in the Mediterranean area and the near east. There is general agreement that this nematode shares the host range of *H. avenae*. However, at least twenty plant species, among cereals and cool season grasses, are reported as hosts for this nematode (SUBBOTIN *et al.*, 2010b).

The pea cyst nematode, *Heterodera goettingiana* Goffart, is common in some Italian regions, especially in the south of the country, where it damages pea, broad bean, vetch and grass pea. Besides, several other species in the genera *Pisum* and *Vicia*, including wild species, are hosts for the nematode. Moreover, species of other genera, such as *Asperula arvensis* L., *Sonchus oleraceus* L., *S. asper* L. (DI VITO and GRECO, 1986; SUBBOTIN *et al.*, 2010b), and *Galium aparine* L. (GRECO, personal communication) have been found to be hosts for the nematode in Italy.

The carrot cyst nematode, *Heterodera carotae* Jones is, instead, a species having a very narrow host range. The nematode is spread in limited areas, as are those cultivated to carrot, in Sicily, Apulia, Latium, Veneto and lately also in Abruzzo (Fucino area). Besides the cultivated carrot, *H. carotae* can reproduce only on wild carrots, rather common in the Mediterranean area, and on some species of *Torilis* (GRECO, 1986; SUBBOTIN *et al.*, 2010b).

STEM AND BULB NEMATODE, *DITYLENCHUS DIPSACI*

This destructive nematode is spread all over the world especially in temperate and subtropical climates. It causes damages during the mild and rather wet period of the year. Therefore, in Italy it affects host plants since mid autumn to mid spring in the south and in autumn and late winter-spring in the north, especially when the temperature is in the range 15-20 °C and the plants remain wet for several hours per day because of rain, fog, dew and sprinkler irrigation. The nematode has a wide host range including cultivated and wild plants. In Italy the crops most severely damaged are onion, garlic, strawberry, carrot (mainly in Sicily), broad bean, pea, and alfalfa. Damages to other crops have also been observed. Up to 30 races of the nematode have been reported, each reproducing on a more limited number of host plants. In Italy the most common would be the onion race, but the giant race (very severe to broad bean in Morocco and elsewhere) has also been found. In 1932, STEINER and BUHRER (1932) reported about 200 plant species host for the nematode. However, so far about 500 plant species, belonging to several botanical families are known to be hosts for *D. dipsaci*. In an onion field severely damaged by the nematode in the Apulia region, all the seventeen plant species present contained specimens of the nematode (Greco, 1976). The plant species containing the larger number of nematode specimens per 20 g of plant tissue were *Chenopodium murale* L. (1,801), *Capsella bursa pastoris* Medic. (831), *Alopecurus* sp. (340), *Lamium amplexicaule* L. (785), *Papaver somniferum* L. (775) and *Urtica dioica* L. (700). Moreover, in Sicily (GRECO *et al.*, 2002) the most susceptible wild plants to a population of *D. dipsaci* destructive to carrots, containing rather large numbers of nematode specimens per 10 g fresh tissues, were *Avena fatua* L. (2,930), *Lolium perenne* L. (16,130), *Amni majus* L. (212) and *Galium aparine* L. (112). These four plant species are common in Italy.

ROOT-KNOT NEMATODES, *MELOIDOGYNE SPP.*

They comprise nearly 100 species and several of them have world wide distribution and are considered as the most damaging nematodes on a world basis. The tolerance limits of plant crops to *Meloidogyne* spp. are rather low and often less then one egg or second stage juvenile per cm^3 of soil (GRECO and DI VITO, 2009). The most important species have large host ranges. In Italy are widespread *Meloidogyne incognita* (Kofoid *et* White) Citwood, *M. javanica* (Treub) Chitwood, *M. arenaria* (Neal) Chitwood, and M. *hapla* Chitwood. In southern Italy *M. artiellia* Franklin is spread in Apulia and Basilicata. The first four species attacks both annual and perennial plants, including many wild species. Rich *et al.* (2009), in their review on weeds hosts for *Meloidogyne* spp., report 138 weed plant species as hosts for *M. incognita*, 49 for *M. javanic*a, 48 for *M. arenaria* and 27 for *M. hapla*. Moreover, the same weed species can be host for more species of *Meloidogyne* and also of other nematode genera. In general, most of the weeds growing in summer, especially in irrigated crops, can be host for one or more *Meloidogyne* species. For instance, *Chenopodium* spp., *Solanum nigrum* L. and *Portulaca oleracea* L., common summer weeds in Italy, are good hosts for several species of *Meloidogyne*. For the cool season root-knot nematode, *M. artiellia*, information on weeds hosts are lacking. However, DI VITO *et al.* (1985) demonstrated that, among cultivated plants, only winter cereals, crucifers and leguminous species are hosts for the nematode and, therefore, it is reasonable to assume that weeds of these botanical families, developing from autumn to spring, can be hosts for the nematode.

ROOT LESION NEMATODES, *PRATYLENCHUS SPP.*

The genus *Pratylenchus* includes about 80 species all migratory endoparasites of roots and other below ground plant organs, in which they cause cavities and brownishments and thus referred to as lesion nematodes (CASTILLO and VOVLAS, 2007). In Italy the most widespread species are *P. vulnus* Allen & Jensen on woody

plants, *P. neglectus* (Rensch) Filipjev & Schuurmans Stekhoven, especially on winter cereals, *P. thornei* Sher & Allen on winter cereals and legume, and *P. penetrans* (Cobb) Filipjev & Schuurmans Stekhoven on annual and perennial plants. In the Mediterranean region, it seems that the species attacking cool season crop plants develop poorly on summer plants. *Pratylenchus* spp. have wide host ranges that may include several hundred plant species. Although information on wild plants host for these nematodes are rather scanty, it can be assumed that they can reproduce also on wild plants belonging to the same botanical family of the main host crop plant species.

OTHER NEMATODES

Many other nematode groups have been reported in Italy. Most of them, such as hoplolaimids, the virus vectors longidorids and trichodorids, criconematids, aphelenchids, and a few others, appear widespread. Most of them have also hosts among wild plants. However, the damages they cause, except the virus vectors, are seldom severe.

IMPLICATION IN NEMATODE MANAGEMENT

Although several wild plant species, as a whole or plant extracts, are known to possess nematocidal activity and are under investigations to assess their suitability as substitutes for synthetic nematicides (CHITWOOD, 2002), here we are focusing on the effects of wild plants as alternative hosts for the nematodes (BELAIR and BENOIT, 1996; Covarelli, 1995; RIGGS, 1992) as they can affect nematode control and yield loss of crop plants. Moreover, the reduction of the synthetic nematocides available and their negative impact on the environment, are making the use of integrated pest management (IPM) strategies more than a necessity for nematode management in many crops (DUNCAN and NOLING, 1998).

Rather than eradication of plant-parasitic nematodes from agro-ecosystems, the aim of the nematode management strategies is to reduce soil population densities to below the tolerance limits of the host crop plants (ROBERTS, 1993).

The most important methods considered for an IPM of nematodes, such as nematocides, cultural control through crop rotation and fallow, use of resistant cultivars, weed control, use of cover crops and physical control through soil solarization, are not very effective individually and need to be integrate to obtain satisfactory nematode control (DUNCAN and NOLING, 1998; NOE, 1998; ROBERTS, 1993; STARR *et al.*, 2002).

The efficacy of crop rotations, resistant varieties or fallow can be reduced in the presence of weeds that are alternative hosts for the targeted nematodes (BELAIR and PARENT, 1996). In weedy fields nematodes would reproduce on wild host plants and maintain soil nematode population densities well above the tolerance limit of the subsequent host crop plant and thus cause severe yield loss (SCHROEDER *et al.*, 1994; BIRD and HOGGER, 1973). In the Mediterranean region, the most common root-knot nematodes attack citrus, form galls on their roots but are unable to complete their life cycle. Unfortunately, most of the citrus groves are kept weedy and, therefore, root-knot nematodes reproduce on host weeds and juveniles of the following generations of these nematodes may continuously invade and damage citrus roots.

Working the soil, especially in summer, negatively affect nematodes directly by reducing the movement of these parasites in the soil and increasing their desiccation and indirectly by destroying weeds or plant residues that can host endoparasitic nematodes (NORTON, 1978).

Some authors found that weeds can affect nematodes not only as alternative hosts. Weeds present in the soil can protect endoparasitic nematodes from nematocides as reported by THOMAS *et al.* (2004) for tubers of *Cyperus esculentus* L. and *C. rotundus* L. that protected the nematode *Meloidogyne incognita* from 1,3-dichloropropene. In some cases, as that of the nematodes *Ditylenchus dipsaci* and *Aphelenchoides* spp., attacking aerial plant parts, weeds may indirectly favour nematode attacks. These nematodes are favoured when plant parts are wet following sprinkler irrigation, fog or dew. Therefore, the presence of heavy weed infestations maintain the host crop plant wet for a longer period even during the sunny hours of the day and thus favours nematode infestation. However, some weeds may help in suppressing nematodes by releasing into the soil antagonistic phytochemicals present in root exudates or following plant tissues decomposition (CHITWOOD, 2002). Therefore, in some cases, proper management of these plants could help in suppressing nematode population densities.

Chemical control of weeds may also directly affect nematodes or indirectly interact with nematocides (THOMAS *et al.*, 2005). The mechanisms by which herbicides affect nematodes are not well known. However, BOSTIAN *et al.* (1984) reported that alachlor and trifluralin can increase soybean cyst nematode egg hatch, while BROWDE *et al.* (1994) found that acifluorfen and bentazon reduced number of soybean cyst nematode eggs and juveniles into the soil. Also, SIPES and SCHMITT (1989) reported antagonistic effect between alachlor and the nematocide fenamiphos.

Some nematocides may also directly affect weed species reducing their emergence acting as a pre-emergence herbicide. CSINOS *et al.* (2002) reported that metham sodium alone or combined with 1,3-dichloropropene and chloropicrin completely controlled *Raphanus raphanistrum* L. COVARELLI *et al.* (2010) found that 1,3-dichloropropene increased tobacco yield, due to its ability to control the nematodes *Meloidogyne incognita* and *Meloidogyne javanica* and the weed *Portulaca oleracea* L. FENNIMORE *et al.* (2003) reported that 1,3-dichloropropene, metham sodium and chloropicrin gave a good control of *Amaranthus retroflexus* L. and *Malva parviflora* L.

It appears that the interactions between weeds and nematodes in agricultural production systems are intricate and complex. The role of weed scientists and nematologists in the future will be to identify effective and compatible strategies for Integrated Weed and Nematode Management.

RIASSUNTO

INTERAZIONI NEMATODI-PIANTE INFESTANTI E LORO IMPLICAZIONE NELLA LOTTA CONTRO I NEMATODI

Molte specie di nematodi fitoparasiti hanno centinaia di piante sia coltivate che infestanti come ospiti. In assenza delle colture, le piante infestanti spesso sono ottimi ospiti alternativi dei nematodi dei quali non solo assicurano la sopravvivenza ma anche il mantenimento nel terreno di

livelli più alti delle soglie di danno per le principali colture ospiti. Ciò avviene soprattutto per alcune specie di nematodi cisticoli, tra i quali il nematode cisticolo della barbabietola da zucchero, *Heterodera schachtii,* ad opera di infestanti crocifere e chenopodiacee, del nematode dei bulbi e degli steli *Ditylenchus dipsaci*, dei nematodi galligeni, *Meloidogyne* spp., e dei nematodi delle lesioni *Pratylenchus* spp., ad opera di varie piante infestanti che crescono durante il periodo dell'anno favorevole allo sviluppo dei nematodi di cui sono ospiti. Pertanto, la lotta alle piante infestanti non solo serve ad eliminare i competitori delle piante coltivate ma anche a limitare le popolazioni dei nematodi nel terreno e costituisce una valida e necessaria strategia di lotta contro i nematodi, specialmente in un programma di gestione integrata basato sull'impiego di mezzi di lotta alternativi ai nematocidi di sintesi.

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