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INTERACTIONS BETWEEN NEMATODES AND FUNGI: A CONCISE REVIEW

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Ragozzino A., d'Errico G. – Interactions between nematodes and fungi: a concise review.

A short review of the complex interactions is reported between nematodes and fungi, which are not always clear because of the rhizosphere complexity and inadequate techniques of investigation.

KEY WORDS: soilborne organisms, mycorrhizae, associations, plant diseases.

The report by Atkinson in 1892, dealing with the pronounced effect of root-knot nematodes (*Meloidogyne* spp.) on the expression of *Fusarium* wilt of cotton, enhanced the research on predisposition for fungi infection in nematode-infested plants. Since then, the investigation concentrated especially on interactions between nematodes and several fungi on different host crops. The mass of investigations, accumulated in a few decades, urged several authors to review this subject (MILLER, 1965; PITCHER, 1965; POWELL, 1963, 1971). The ability of the lesion-nematodes of the genus *Pratylenchus* to promote diseases induced by *Verticillia* and *Fusaria* on several host-plants was well known (MILLER, 1965; PITCHER, 1965; POWELL, 1971; EVANS *et al*., 1993). In a short time, it was also clear how nematodes break-down genetic resistances to wilt-fungi: plant varieties ordinarily resistant to fungi become infected by them when previously attacked by nematodes. Most probably, this is related to morphological and physiological changes that occur in the nematode-infected plant (SIKORA, 1992; STIRLING, 1991), although it seems that mechanical woundings caused by nematodes to plants may also induce some host-response that lowers natural resistance to fungi. Therefore, this evidence press the genetists to insert resistance-genes in plants, as it happens in tomato with genes *V* (*Verticillium*) *F* (*Fusarium*), *N* (Nematode) (FASSOLIOTIS, 1987). This genotype choice is based also on field observations on the root-knot-*Fusarium* complex on various hosts. In U.S.A., tests with tomato affected by the complex *Fusarium-Meloidogyne incognita* (Kofoid *et* White) Chitw. showed that 100% of the plants were wilted when this nematode was combined with the fungus, as compared to only 60% when *M. hapla* was present (POWELL, 1971; SAYRE and WALTER, 1991). This could mean that a higher damage is caused by the combination nematode-fungus, compared to the cumulative effects of the single pathogens. Moreover, the experiments showed that the physiological effects on tomato differ with the nematode species. This evidence is true also in other type of combinations: i.e. *Meloidogyne* spp.-*Fusarium oxysporum.* f.sp. *dianthi* (Prill. *et* Delacr.) Raillo on carnation; *Pratylenchus* spp.-*Verticillium* spp. on potato. In the last case, it is evident how the nematode shortens also the incubation-period of the fungus. Furthermore, the mentioned nematode-fungus combinations enhance the nematode development thanks to the CO_2 production by the damaged roots: it is well known that this gas is a powerful nematode attractive (ZUCKERMAN, 1984). In eggplant and tomato the presence of *Verticillium* sp. promotes an increase in reproduction of *Pratylenchus* spp.

The so far mentioned interactions show a clearly synergistic relationship. On the other side, the sting nematode, *Belonolaimus longicaudatus* Rau, an aggressive pathogen and promoter of *Fusarium*-wilt in cotton, delays considerably the wilting, which often does not express at all. This happens on cotton also when *Meloidogyne* spp. are involved. Meanwhile, the histological studies of diseased plant tissues showed that galled roots are more susceptible to fungal invasion than non-galled ones. Hypertrophic tissues promote highly vigorous growth of several fungi. Research carried on tomato by BOWMAN and BLOOM (1966) using a split-root techniques, found that a portion of the root system having not been exposed to nematode damage was predisposed to *Fusarium* wilt as it was the part of the root inoculated with nematodes. This means that root predisposition to fungal invasion is not restricted to galled areas or to sites of nematode activity. Surprisingly, a research on tobacco has shown that root-knot nematodes make the plant susceptible to root-rot by common inhabitants of soils, such as species of *Curvularia*, *Penicillium* and *Trichoderma*, the last one described as antagonistic of phytopathogenic fungi (COMBETTES, 1983). It seems that the galled tissues are easily invaded by the fungi which becomes phytopatogenic. Infact, when any of the mentioned fungi is added to healthy tobacco roots, in the greenhouse, neither tissue invasion nor necrosis are evident. Antagonistic relationship occurs between *Globodera rostochiensis* (Woll.) Behrens and *Colletotrichum atramentarium* (Berk. *et* Broome) Taubenh, the fungus causing the black-dot of some solanaceous plants (tomato, potato). *C. atramentarium*, presumably due to exudate production, decreases hatching of both cysts and eggs of the nematode, and severely reduces root invasion by juveniles. Furthermore, the ratio of males to females increases and, accordingly, the number of cysts is reduced (POWELL, 1971; DUNCAN, 1991).

Similar, but opposite, relationship has been observed

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between other sedentary, endoparasitic nematodes (*Heterodera* spp., *Meloidogyne* spp. *Globodera* spp.) and some phytopathogenic fungi: the nematodes prevent the tomato root invasion by fungi. It seems that antibiotic-like substances are involved.

An interesting relationship has been established between nematodes of the genus *Aphelenchus* and some endomycorrhizal fungi of the genus *Glomus*. In pine, the nematodes prevent the association (endo-infection) of the fungus to the roots, and so fumigant nematicides must be used to disinfest the soil. Thereafter, the fumigation increases the endomycorrhizal infection of pine roots also because the conifer utilizes the devitalized nematodes as an excellent *pabulum* (SUTHERLAND and FORTIN, 1968; RODRIGUEZ-KABANA and CURI, 1980; BROWN and KERRY, 1987; BAKHTIAR *et al.*, 2001; PEREZ-MORENO and READ, 2001).

Interaction nematodes-endophytes is also interesting. The endophyte *Acremonium coenophialum* Morgan-Jones *et* Gams of the tall fescue (gen. *Festuca*) confers resistance to *Meloidogyne marylandi* Jepson *et* Golden and *Pratylenchus scribneri* Steiner, possibly by different mechanisms (KERRY *et al.*, 1982; PEDERSEN *et al.*, 1988; KIMMONS *et al.*,1990; SCHARDL, 1996; WEST *et al.*, 1988).

The few cases cited above concern more or less synergetic or antagonistic interrelationships between nematodes and fungi. It is now interesting to mention briefly some examples of true, reciprocal parasitism. Some species of the genus *Aphelenchoides* feed on cytoplasm of fungal hyphae they pierce by the strong stylet (BARRON, 1977). Such behaviour is so steady and marked that its use has been attempted in biological control trials, mixed with *Trichoderma* spp., against *Botrytis cinerea* (Pers.:Fr.) and *Sclerotinia sclerotiorum* (Lib.) de Bary (POWELL, 1971). Unfortunately, the results were not always satisfactory, probably because of rhizosphere complexity (SAYRE and WALTER, 1991).

Some fungi can infect specially the nematode-eggs with different mode of action. *Verticillium chlamydosporium* Goddard can infect eggs of *Heterodera avenae* Wollenweber only within the third day from the cyst-hatching. Strain 251 of *Paecilomyces lilacinus* (Thom) Samson has a clear effectiveness against the *Meloidogyne* spp. eggs (GUNASEKERA *et al.*, 2000; JANSOON and NORDBRING-HERTZ, 1983; SCHENCK, 2004); in Italy, it has been processed recently a commercial product to use as biocontrol agent in the field (BENUZZI, 2010).

Plant pathogenic nematodes are also parasitized by other nematophagous fungi; the dagger-nematode *Xiphinema* spp. and cyst nematodes *Heterodera* spp. and *Globodera* spp. are infected by *Catenaria auxiliaris* (Kuehn), *Nematophtora gynophila* Kerry *et* Crump, *Verticillium chlamydosporium* Goddard and *Hirsutella* spp.

A large body of evidence converges to conclude how the matter we shortly exposed needs deeper investigation, also through the use of more advanced techniques, such as the molecular ones.

The recovery of fungi parasitizing nematodes seems very widespread. The first investigated case was related with the cereal cyst-nematode (*CCN*), *Heterodera avenae* Wollenweber. As it would be expected, the continuous cropping of oats did not result in high population of *CCN* in oats fields. Three species of fungi were found parasitizing female and cyst of *CCN* (KERRY *et al.*, 1982). Egg masses of *Meloidogyne javanica* (Treub) Chitwood, in soils of peach-orchards, were colonized by the fungus *Dactylella oviparasitica* Stirling *et* Mankau. The same fungus, on the contrary, was unable to control the same root-knot nematode on tomato and grape roots (SAYRE and WALTER, 1991). More predacious habits are found in fungi of the so called nematode-trapping group, which have typical anastomised ringlets, costricting rings or buttons which capture and digest the nematodes (JANSOON, 1982; JANSOON and NORDBRING-HERTZ, 1979; 1980; 1983). The attraction of nematodes to nematophagous fungi has been investigated and, in all cases, attractive compounds have been found (chemotactic factors) (ZUCKERMAN, 1984). Fungal traps can be spontaneously produced or they can be induced by nematodes (FIELD and WEBSTER, 1977; JANSOON and NORDBRING-HERTZ, 1979). The most important predacious fungi belong mostly to the genera *Arthrobotrys*, *Dactylaria*, *Dactylella*, a monophyletic and isolated clade among an unresolved cluster of apothecial ascomycetes which are active especially against root-knot nematodes (*Meloidogyne* spp.) (JANSOON and NORDBRING-HERTZ, 1980). In France, some years ago, a commercial preparation, named Royal 350, of *Arthrobotrys irregularis* (Matr.) Mekht. was used in *Meloidogyne* biocontrol. Its practical use was not always satisfactory, probably because of high variability of the ryzosphere (COMBETTES, 1983).

RIASSUNTO

INTERAZIONI TRA NEMATODI E FUNGHI: UNA CONCISA REVISIONE

Si riporta una breve sintesi sulle interazioni tra nematodi e funghi. Le complesse e sofisticate relazioni non sono sempre ben chiare per le scarse indagini e le molteplici interferenze con gli altri componenti biotici della rizosfera.

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