Plant-Parasitic Nematodes Affecting Citrus

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A number of plant-parasitic nematodes have been associated with citrus (Table 1). However, only *Belonolaimus longicaudatus* (21), *Hemicycliophora arenaria* (25), *Meloidogyne* spp. (3), *Pratylenchus brachyurus* (20), *P. coffeae* (19), *P. vulnus* (10), *Radopholus citrophilus* (22) and *Tylenchulus semipenetrans* (5) have been associated with crop damage. Crop losses associated with these plant-parasitic nematodes range from slight to severe and are influenced by a number of factors which include rootstock, nematode species and/or biotype and environmental conditions. All plant-parasitic nematodes associated with citrus are obligate parasites living in soil or roots and derive their nourishment from tree roots. Their mode of parasitism ranges from ectoparasitic forms which occur in the rhizosphere and insert their stylets into roots to feed, to migratory endoparasites which invade and move within roots as they feed, to the sedentary endoparasites which, in essence, stimulate the host to nurture the female nematode and thereby perpetuate the nematode populations.

On the basis of geographic distribution and influence on tree health, some of these nematode species are of great concern to man. Consequently, this presentation will focus on three nematodes that adversely affect citrus in Florida, and which are either widely distributed or present a significant threat to citriculture throughout the world. They are the burrowing, the citrus and the lesion nematodes.

The Burrowing Nematode

The burrowing nematode, *Radopholus citrophilus* Huettel, causes a disease of citrus in central Florida called spreading decline (22). Nematode feeding in fibrous roots causes cessation of apical meristem activity and destruction of root cells. Lesions may coalesce and eventually roots die. An infested tree has approximately 50% fewer functional feeder roots than a healthy tree under Ridge conditions. *Radopholus citrophilus* populations vary with depths. From 0 to 15 cm, they are found less frequently, and in smaller numbers, than at lower depths. Highest populations occur from 60 to 150 cm deep (8). At soil depths between 0-30 cm, 18% of the roots are destroyed; between 25 and 75 cm, 25 to 30% are destroyed; and at depths below 75 cm, 90% of the feeder roots are destroyed.

Infested trees have sparse foliage and dead twigs with branching ends.

Table 1. Plant parasitic nematodes associated with citrus.

Aphelenchoides	Merlinius
Belonolaimus	Paralongidorus
Cacopaurus	Paratrophurus
Criconema	Paratylenchus
Criconemoides	Peltamigratus
Discocriconemella	Pratylenchoides
Ditylenchus	Pratylenchus
Dolichodorus	Radopholus
Gracilacus	Rotylenchulus
Helicotylenchus	Rotylenchus
Hemicriconemoides	Scutellonema
Hemicycliophora	Sphaeronema
Heterodera	Telotylenchoides
Hirschmanniella	Telotylenchus
Hoplolaimus	Tetylenchus
Hoplotylus	Trichodorus
Lobocriconema	Tylenchorhynchus
Longidorus	Tylenchulus
Macroposthonia	Tylenchus
Meloidogyne	Xiphinema

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Trees are undernourished; leaves are small, and fruit are small and usually sparse. Fruit set is reduced and trees wilt readily under drought conditions. Symptoms are generally present on groups of trees and the number of affected trees increases with time; hence, the name "spreading decline" (22).

Radopholus citrophilus is morphologically identical to its sibling species, *R. similis*. The two species differ in their host range, karyology, protein and isozyme composition. Citrus is not host of *R. similis*, but is a host of *R. citrophilus* which has a dramatic effect on tree health (9). Females range in size from 458 to 729 μm and are 17 to 24 μm in diameter. Males range from 447 to 653 μm in length and 14 to 21 μm in diameter. The female has a strong stylet (16 to 20 μm) with distinct basal knobs. The weak male stylet is small with no basal knobs (23). Eggs are laid by adult females in roots and in soil. First-stage juveniles develop within the egg, molt, and the second-stage juveniles hatch from the egg, infect roots, and increase in size in two subsequent molts. Fertilization is not essential for reproduction to occur.

The optimum temperature for growth and reproduction of *R. citrophilus* is 24°C; however, nematode reproduction and root invasion may occur from 12°C to 32.5°C (6). In the upper root zone, (0 to 25 cm) soil temperatures are variable and can exceed the limits for root growth and nematode development. Nematode activity is greatest from 30 to 75 cm in depth where temperatures are more constant and well within the range required by *R. citrophilus*. Population densities of *R. citrophilus* fluctuate with annual temperature oscillations. Nematode populations peak in Florida from October to December (7).

The burrowing nematode is an obligate parasite and thus must have a living host as a food source. The nematode does not survive for more than 6 months in fallow soils. However, *R. citrophilus*' wide host range (ornamentals, weeds, and cultivated crops) often enables populations to persist in the absence of citrus. In Florida, *Radopholus citrophilus* has been detected in every county where commercial citrus is grown; however, spreading decline occurs only in deep, fast-draining, sandy areas in DeSoto, Hardee, Highland, Hillsborough, Lake, Marion, Orange, Osceola, Pasco, Polk, Seminole and Sumter counties. Burrowing nematode-infested trees growing in shallow, poorly drained soils and soils with organic content and better water retention have less severe symptoms.

Spreading decline has been controlled for 25 years by the "push and treat method." When an infestation is found, nematode distribution is determined, infested trees and healthy trees bordering the infestation are pushed out and burned in place. The site is then disked and roots, which could harbor nematodes, are removed from the field. The site is fumigated and then allowed to remain fallow for a 2-year period. Herbicides are used during this period to maintain the area free from weeds which may serve as alternate hosts of the nematode.

Chemical barriers around infested sites are maintained to protect adjacent noninfested groves. Barrier strips 4.8 to 9.8 m wide are treated with a soil fumigant at 6-month intervals. The buffer zone is maintained weed-free. The planting of burrowing nematode-resistant and -tolerant rootstocks is encouraged. Most of the commonly planted citrus rootstocks, such as rough lemon (*Citrus limon* Burm. f.), sour orange (*C. aurantium* L.), Cleopatra mandarin (*C. reticulata* Blanco), Volkamer lemon (*C. limon*), *C. macrophylla*, sweet lime and Rangpur lime (*C. reticulata* var. *austera* hyb.?) are susceptible to *R. citrophilus*.

Milam lemon (*C. limon*), Ridge Pineapple sweet orange (*C. sinensis* (L.) Osbeck) and Carrizo citrange (*Concirus trifoliata* Raf. X *C. sinensis*), which limit nematode population development, grow well in the presence of small populations, and are considered resistant or tolerant.

Milan lemon and Carrizo citrange limit nematode development by reacting to nematode feeding in a hypersensitive manner. Resistant and susceptible rootstocks are infected equally under experimental conditions suggesting that resistance is indeed the result of events which occur in the host in response to the nematode activity.

Reports of spreading decline symptoms in Carrizo citrange and Milam lemon rootstock plantings suggest that biotypes of *R. citrophilus* may be developing (17). This emphasizes the need to reduce nematode populations prior to planting. Also, postplant treatments which enhance plant growth and/or reduce nematode populations should be used in order to minimize damage to trees resulting from nematode feeding and the development of resistance-breaking races. This also emphasizes the need to develop rootstocks which have a broad genetic base.

The Citrus Nematode

The citrus nematode, *Tylenchulus semipenetrans* Cobb, occurs throughout the citrus-growing regions of the world. In Florida, this nematode is distributed in all countries where citrus is commercially grown. Nematode populations are greatest in Florida in April-May and November-December (18). Symptoms associated with citrus nematode infestations include stunting of young trees (replant problem), and a "slow decline" or older trees. Slow decline is typified by small leaves, smaller and fewer fruit, reduced growth and twig dieback (26). Problems with citrus nematodes cannot be diagnosed by tree condition; yields may be reduced in the absence of obvious symptoms.

The citrus nematode is semiendoparasitic. Females range from 0.35 to 0.40 mm long with swollen, saccate bodies. The anterior half of the female penetrates the root. The posterior region, which is swollen, contains the vulva and excretory pore which produce eggs and a protective mucilaginous matrix, respectively. Larvae develop in the eggs and upon molting, leave the egg. Two types of second-stage juveniles (0.28 to 0.36 mm) emerge from the egg mass. Males continue to molt to the adult stage (0.30 to 0.41 mm) without feeding. The stylet, although distinct, is weak and the esophagus is degenerate in the adult citrus nematode male (24). Female larvae must infect roots and stimulate the formation of a feeding site within the root cortex. This feeding site is comprised of nurse cells which contain granular cytoplasm and are rich in starch. The cells surround the head. The complete life cycle requires 6 to 8 weeks (4).

The citrus nematode has a rather narrow host range. Hosts include citrus and related plants in the rutaceae, olive (*Olea europaea* L.), grape (*Vitis vinifera* L.), lilac (*Syringia vulgaris* L.), palmetto (*Sabal palmetto* L.), and a grass (*Andropogon rhizomatus* L.). *Severinia buxifolia* and *Poncirus trifoliata* are resistant to the citrus nematode (1). Currently, all commercial resistant rootstocks derive their resistant germplasm from *P. trifoliata. Severinia buxifolia* germplasm has not been utilized because of incompatibility problems. Swingle citrumelo, a hybrid (*C. paradisi* X *P. trifoliata*), is highly resistant to the citrus nematodes in Florida (14); however, populations from other parts of the USA reproduce to a limited extent, on this rootstock (16).

The citrus nematode appears to have several races (11). Citrus, olive and grass biotypes have been identified. Of particular importance is the *Poncirus* biotype which can reproduce on *P. trifoliata.* The fact that biotypes exist emphasizes the need to diversify the germplasm of citrus nematode-resistant rootstocks.

Resistance of *P. trifoliata* and *S. buxifolia* to the citrus nematodes appears to involve both preinfection and postinfection events. Fewer nematodes have been associated with the rhizoplane of resistant roots and actually infecting roots of resistant varieties. Following infection, resistance may involve a hypersensitive-type response or it may be associated with the development of abnormal nurse cells within the feeding site (13).

The Lesion Nematodes

The lesion nematodes, *Pratylenchus brachyurus* and *P. coffeae*, have been associated with damage to citrus. *P. brachyurus* is common in Florida citrus groves but generally populations remain small. In contrast, *P. coffeae* severely affects tree health and large populations may develop on citrus. *Pratylenchus coffeae* is limited in its distribution in Florida (40 ha of commercial citrus), but has been reported to be pathogenic to citrus in other citrus-growing regions of the world. The biology and symptomatlogy associated with lesion nematodes are similar to those of *R. citrophilus* under Florida's environmental conditions (15). Lesion nematodes remain motile and vermiform throughout most of their life cycle. Adults range from 0.45 to 0.70 mm in length and both males and females have strong, well-developed stylets. *Pratylenchus* spp. have wide host ranges and feed within the root cortex of host plants.

Although numerous germplasm sources have been evaluated, no resistant rootstock is commercially available for the control of the lesion nematodes. Wampi (*Clausenia* sp.) is resistant to populations of *P. coffeae* in Southeast Asia (2).

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The Present Status of Citrus Virus and Virus-Like Diseases in China

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Abstract: Citrus yellow shoot (Huanglongbing), exocortis and tristeza have been found in several provinces of the mainland of China. Psorosis and xyloporosis have also been reported in Taiwan Province (6, 9). Satsuma sudden wilt and yellow ring of sweet orange on trifoliate orange which are similar to virus diseases in symptomatology, also occur in China (22, 25).

Citrus Yellow Shoot (Huanglongbing)

Citrus yellow shoot (CYS) is the most serious disease in Chinese citriculture, and is prevalent in the southern citrus-producing area of China. Likubin in Taiwan Province is probably the same disease (2).

The recorded history of CYS in Guangdong Province began in 1919. In areas where the disease is prevalent, a citrus orchard isolated from existing diseased orchards may be seriously damaged 8-9 years after planting. New plantings near orchards with CYS incidence often are fatally damaged before bearing.

Almost all citrus species and scion-stock combinations are susceptible to CYS; however, trifoliate orange (*Poncirus trifoliata* (L.) Raf.) does not show strong symptoms after infection.

Yellow shoot in the primary stage of the disease and leaf mottling yellows are characteristic symptoms.

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