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Hemicriconemoides Species as Crop Damaging Parasitic Nematodes in Florida[1]

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INTRODUCTION: Sheathoid nematotodes (*Hemicriconemoides* spp.) are sexually dimorphic plant-parasitic nematodes occurring mainly in warm climates. Their common name is derived from the morphological features of the females that have the cuticle of their body covered by a loosened outer cuticular sheath, which is attached to the main body at the head and vulva (Fig. 1). The cuticular sheath is absent in males and juveniles (Figs. 2, 3). The genus *Hemicriconemoides* is represented by 52 species (Geraert 2010). The identification of these nematodes is difficult because many morphological characters of diagnostic value overlap in some species. Molecular data are available for some species, but many DNA sequences have been obtained from populations collected in geographical areas different from those where the species were described. The molecular characterization of populations of sheathoid nematodes from the type localities of the original description has been conducted only for a few species, which include: *H. alexis* Vovlas, 1980, *H. chitwoodi* Esser, 1960, *H. macrodorus* Vovlas, Troccoli & Castillo, 2000 and *H. minutus* Esser, 1960 (Van Den Berg *et al*. 2014).

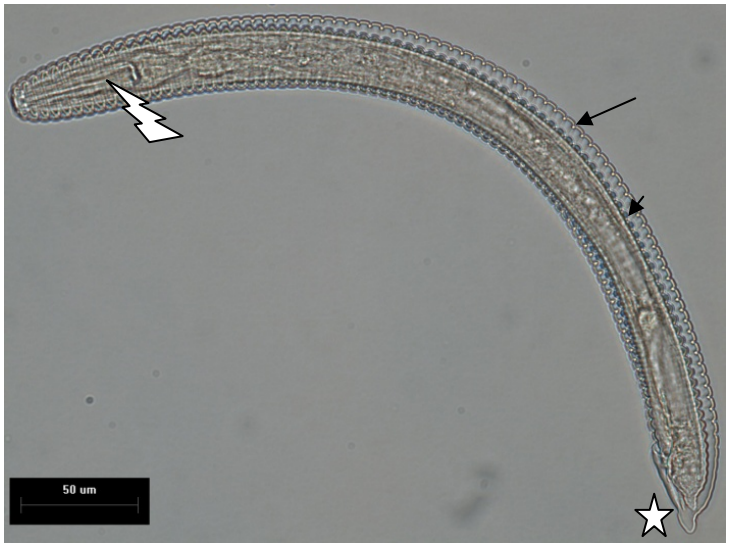

Fig. 1. Female *Hemicriconemoides wessoni*, a parasite of turf grass in Florida. Note the loosened outer cuticular sheath (long arrow) that covers the body cuticle (short arrow) and the characteristic knob-like tail tip (star). The robust stylet is indicated by a zig-zag arrow. Photography credit: Jason Stanley.

According to Lehman (2002), the sheathoid nematodes reported in Florida include: *H. amurensis* Eroshenko & Volkova, 1986, *H. brachyurus* (Loos, 1949) Chitwood & Birchfield, 1957, *H. brevicaudatus* Dasgupta, Raski & Van Gundy, 1969, *H. chitwoodi*, *H. cocophillus* (Loos, 1949) Chitwood & Birchfield, 1957, *H. gaddi* (Loos, 1949) Chitwood & Birchfield, 1957, *H. kanayaensis* Nakasono & Ichinoe, 1961, *H. mangiferae* Siddiqi, 1961, *H. minutus*

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Esser, 1960, *H. nitidus* Pinochet & Raski, 1975, *H. parataiwanensis* Decraemer & Geraert, 1992, *H. strictathecatus* Esser, 1960, and *H. wessoni* Chitwood & Birchfield, 1957. However, molecular studies (still in progress) on the characterization of Florida sheathoid nematodes suggest that other undescribed species exist in the state. In Florida, sheathoid nematodes are commonly found in cultivated and uncultivated lands in association with a wide range of plants. It is not unusual to find two or more species occurring together.

Fig. 2. Male *Hemicriconemoides* sp. Note the spicule (arrow) which is a component of the copulatory apparatus in the posterior portion of the nematode body and the lack of a stylet in the anterior portion of the body. Photography credit: Jason Stanley.

Fig. 3. Juvenile *Hemicriconemoides* sp. Note the lack of a loosened outer cuticular sheath. The tip of the stylet is indicated by an arrow. Photography credit: Jason Stanley.

Fig. 4. Details of the cuticle of a juvenile *Hemicriconemoides* sp. Note the rows of scales (arrows) that mark the cuticle. Photography credit: Jason Stanley

NEMATODE DEVELOPMENT AND BEHAVIOR: The studies on the biology of sheathoid nematodes have dealt mainly with their developmental stages which consist of egg, four juvenile stages (J1-J4) without a sheath and adult (female and male). The first biological observations on sheathoid nematodes were conducted by Fassuliotis (1962) and subsequently amended by Dasgupta *et al.* (1969). Both authors used a population of *H. chitwoodi* on camellia grown in pots. The results of these studies indicated that the first two juvenile stages (J1 and J2) of this species develop in the egg. J2s hatch from the embryonated egg, feed on the roots and molt into J3s and then into J4s, which mature into the adult females with a sheath or the adult males without a sheath. Males and juveniles are found in the soil with females. Males have a degenerated esophagus and do not feed (Fig. 2), whereas the juvenile stages (J2-J4) feed on the roots and have the cuticle marked by rows of scales (Fig. 4). These and other studies (Loos 1949; Whitlock and Steele 1960) suggest that sheathoid nematodes are obligate migratory ectoparasites feeding on plant roots. However, there is lack of information on the parasitic habits of these species. Recently, the results of nematological analyses of soil and root samples collected from declining *Washingtonia robusta* H. Wendl. palms in southern Florida revealed an infestation of *H. strictathecatus*, which in some areas of the infested field reached population levels of 340 specimens/100 cm^3 of soil.

The examination of the infested palm roots showed that the females of this nematode have semiendoparasitic habits. These females were partially embedded with the anterior portion of their body inside the root after penetrating the epidermis and the periphery of the cortical parenchyma in order to feed on cortical cell tissue (Fig. 5). Feeding of the observed specimens occurred on the feeder root axis in proximity of the root tip. These specimens remained attached to the root even after the removal of the soil particles that coated the root. Although, histological observations of the nematode feeding sites were not conducted, the parasitic habits of the *H. strictathecatus* specimens we observed were similar to those reported for *Hemicycliophora* species, which feed mainly on the root tips (Klinkenberg 1963; McElroy and Van Gundy 1968).

INTERACTIONS WITH OTHER PATHOGENS AND AGRONOMIC FACTORS: The observations on the stunted *W. robusta* palms infested by *H. strictathecatus* indicated concomitant parasitization of the spiral nematode *Helicotylenchus pseudorobustus* (Steiner, 1914) Golden, 1956 and infection by a fungus (*Pythium* sp). The nematode infestation and fungal infection were favored by excessive conditions of soil moisture, which induced root rot and consequent palm decline. A similar combination of excessive soil moisture and high population levels of *H. mangiferae* was observed by McSorley *et al.* (1980) on declining mango trees in South Florida. It seems that in the conditions of southern Florida where loamy Rockdale soils are predominant, flooding and overwatering favor the increase of sheathoid nematode population levels and predisposes these trees to root rot and decline.

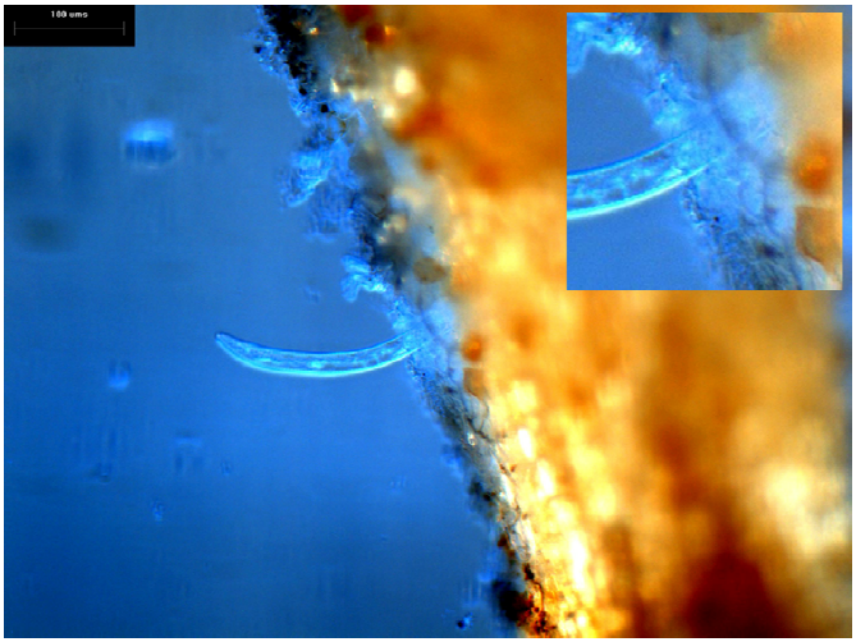

Fig. 5. Parasitic habits of a female *Hemicriconemoides strictathecatus* on a feeder root of *Washingtonia robusta*. Note the posterior portion of the nematode body protruding from the root surface, whereas the anterior portion of the body has penetrated the epidermis and portion of the cortical parenchyma tissue (see insert). Arrow indicates the vulva. Photography credit: Jason Stanley.

SYMPTOMS: With the exception of a few species, generally there is no visible symptom associated with sheathoid nematode infestations on most plants and crops. The symptoms reported in the literature on plants infested by these parasites consist of stunting, premature wilting, leaf yellowing, root malformation, necrosis of cortical root tissues and related signs characteristic of nutrient deficiencies (McSorley *et al*. 1980). The declining *W. robusta* palms infested by *H. strictathecatus* in southern Florida showed leaf yellowing and necrosis of the leaf blade (Fig. 6) and roots.

Fig. 6. Declining *Washingtonia robusta* palms infested by *Hemicriconemoides strictathecatus* and growing in a Rockdale soil prone to flooding in South Florida. Photography credit: Ana Ochoa.

DAMAGE, ECONOMIC RELEVANCE AND MITIGATING MEASURES: While a few sheathoid nematode species have been implicated with the decline of some crops, most of them are not considered aggressive parasites. In Florida and abroad, damage is documented for only a few species and a few crops, which include litchi (*Litchi chinensis* Sonn.) and mango (*Mangifera indica* L.) infested by *H. litchi* Edward & Misra, 1964 (Nath et al. 2008;

Liu and Feng 1995) in Taiwan and *H. mangiferae* (Milne 1982; McSorley 1992) in Florida and South Africa; sugarcane (*Saccharum officinarum* L.) by *H. cocophillus* (Cadet and Albrecht 1992) in Martinique; and tea (*Camellia sinensis* (L.) O. Kuntze) by *H. kanayaensis* (Nakasono and Ichinohe 1961) in Japan. In Florida, one sheathoid nematode species, *H. wessoni* (Fig. 1) has economic relevance for the sod grass industry because it suppresses the growth and vigor of highly maintained grasses at population levels ranging from 300-1000 specimens/100 cm^3 of soil (Crow 2014). Turfgrass decline induced by the sheathoid nematode *H. wessoni* has been reported in Florida for many years (Dunn 1984; Crow 2014). The damage induced by this nematode on turf grasses, including Bermuda grass (*Cynodon dactylon* (L.) Pers.), seashore paspalum (*Paspalum vaginatum* Elliot), St. Augustine grass (*Stenotaphrum secundatum* (Walt.) O. Kuntze), and *Zoysia* sp., is similar to that caused by other nematode parasites and consists of yellowing of foliage, lack of vigor and thin ground coverage. Balanced irrigation, fertilization and the application of nematicides are the major management practices implemented in Florida to mitigate the nematode damage on sod grasses. According to the field observations conducted by McSorley *et al*. (1980), mitigating measures such as balanced irrigation regimes, drainage of standing water and the implementation of appropriate agronomic practices in mango orchards improved the vigor of the trees infested by *H. mangiferae*. These agronomic practices also should benefit other declining plants infested by sheathoid nematodes.

CONCLUDING REMARKS: With the exception of *H. mangiferae*, *H. strictathecatus* and *H. wessoni*, which have been involved in plant stunting and decline, the other species reported in Florida have negligible economic relevance. There is evidence (Fassuliotis 1962) that *H. chitwoodi* is able to parasitize camellias, but no declining symptoms have been reported on this ornamental. This species and *H. minutus* occur commonly in hardwood forests of Northern and Central Florida in association with ring, spiral, sting and other plant parasitic nematodes of Florida hardwood forests. *Hemicriconemoides cocophillus*, which has been associated with sugarcane decline in Martinique, has been detected in southern Florida and the Keys on coconut palms. However, these infested palms did not show evidence of damage. There is a lack of information about the economic importance of the other sheathoid nematodes reported in Florida. The identity of these nematodes is still uncertain and needs to be verified by additional morphological and molecular studies.

SUMMARY: Thirteen sheathoid nematode species have been reported in Florida. Three of these species, *Hemicriconemoides mangiferae*, *H. strictathecatus* and *H. wessoni* have been involved with damage of fruit and ornamental trees (*H. mangiferae* and *H. strictathecatus*), and also ornamental turfgrasses (*H. wessoni*) in the state. Female *H. strictathecatus* have semiendoparasitic migratory habits and use the anterior portion of their body to penetrate inside the root to feed on the cortical parenchyma tissue. So far, the molecular characterization of populations of sheathoid nematodes from type localities of the original description of each species has been conducted only for four species, *H. alexis*, *H. chitwoodi*, *H. macrodorus* and *H. minutus*.

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