Chapter 10
Nematodes of Agricultural Importance in North and South Carolina

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10.1 Introduction

North Carolina's agricultural industry including food, fiber, ornamentals and forestry, contributes $84 billion to the state's annual economy, accounts for more than 17% of the state's income, and employs 17% of the work force. North Carolina is one of the most diversified agricultural states in the nation. Approximately, 50,000 farmers grow over 80 different commodities in North Carolina utilizing 8.2 million of the state 12.5 million hectares to furnish consumers a dependable and affordable supply of food and fiber. North Carolina produces more tobacco and sweet potatoes than any other state, ranks second in Christmas tree and third in tomato production. The state ranks nineth nationally in farm cash receipts of over $10.8 billion (NCDA Agricultural Statistics 2017).

Plant parasitic nematodes are recognized as one of the greatest threat to crops throughout the world. Nematodes alone or in combination with other soil microorganisms have been found to attack almost every part of the plant including roots, stems, leaves, fruits and seeds. Crop damage caused worldwide by plant nematodes has been estimated at $US80 billion per year (Nicol et al. 2011). All crops are damaged by at least one species of nematode. Most plant parasitic nematodes live in soil and damage plants by feeding in large numbers on roots impairing the plant's ability to take up water and nutrients. Severe root damage caused by nematodes typically results in aboveground symptoms that may include stunting, yellowing of leaves, incipient wilt, loss of plant vigor and/or an overall general decline in plant performance. Damage is often more pronounced when plants are under stress from lack of

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water or nutrients or when damaged by other diseases or insects. Although nematodes rarely kill plants, they can drastically limit plant growth and yields. Plant parasitic nematodes are usually confined to localized areas in soil and spread very slowly by their own power. However, they may be dispersed more rapidly by movement of infested soil through cultivation, on soil clinging to farming tools and tillers, in water, wind or on roots of transplants.

The Nematology Research Program in North Carolina began with C. J. Nusbaum who joined the Plant Pathology Department of North Carolina State University (NCSU) in 1948. In 1951, Nusbaum observed that pre-plant soil fumigation was "growing in popularity" around the nation, while in North Carolina "comparatively few growers have used these treatments extensively". He began testing the efficacy of nematicides for local conditions and commodities, particularly tobacco and, by 1956, at least half of the tobacco land (approximately 81,000 ha) was fumigated and losses from root disease were decreasing rapidly. Due to the increased awareness of nematode damage to the state's other primary crops such as peanuts, soybeans, cotton, ornamentals, fruits and vegetables, Nusbaum advocated for a nematode assay project to examine population dynamics and epidemiology. J. N. Sasser joined NCSU Plant Pathology Department in 1953 and brought widespread recognition and public acclaim to the Nematology program. Sasser was at one time referred to as "the most widely known nematologist around the world". He became a pioneer in the work of identifying host races within nematode species, particularly *Meloidogyne* spp., by using differential host specificity. Perhaps most significant, though, was his efforts to expand and organize the discipline of Nematology on a regional, national and international basis. In 1975, he obtained a multimillion-dollar grant from the U.S. Agency for International Development to launch the International *Meloidogyne* Project (IMP) to focus on the biology, ecology, genetics, pathogenicity and control of root knot nematodes affecting economic food crops in the developing world.

In the 1960s and 1970s, many scientists helped guide and develop the Nematology program at NCSU during its height of productivity. Among the most unique was the husband and wife research and teaching team of H. H. Triantaphyllou and A. C. Triantaphyllou. H. H. Triantaphyllou joined NCSU in 1954 and A. C. Triantaphyllou in 1960. Their primary contributions were in the areas of taxonomy, morphology, ultrastructure, developmental biology, cytogenetics and biochemistry, particularly in regards to *Meloidogyne* and *Heterodera*. A. C. Triantaphyllou and his student, P. R. Esbenshade, developed new biochemical methods to assist in reliable identification of *Meloidogyne* species (Esbenshade and Triantaphyllou 1985, 1987, 1988). He also developed and refined a technique for fixing and staining the chromosomes of nematodes.

C. J. Nusbaum first conceived of a nematode assay service for North Carolina in 1953. Four years later, Nusbaum and W. M. Powell started basic research and application towards this goal. In 1965, a 5-year plan for development of an advisory service was funded by the state of North Carolina. In 1966, K. R. Barker was hired by the NCSU Plant Pathology Department to research and develop a pilot nematode assay program. His research focused on charting the complex interactions of plant parasitic nematodes with their hosts and environment. He established the nematode assay program with funds provided by the state legislature. Barker and associates developed the semi-automatic elutriator, a new tool for extracting nematodes from soil. Barker's long career also was focused on conceptual breakthroughs regarding quantitative population dynamics and related application to crop performance. He modified techniques for estimating crop damage based on the population and distribution of nematodes in fields. Studies on the role of the environment on nematode populations, particularly seasonal changes in nematode densities, allowed the formulation of practical nematode damage thresholds and hazard indices that helped put diagnostic work and nematode disease management for a wide spectrum of economically valuable commodities on a new scientific basis (Barker and Noe 1987). The research was expanded by extensive excellent work by colleagues and graduate students in the NCSU Plant Pathology Department. By 1974, the Nematode Advisory Service was on solid conceptual and practical footing, and was transferred to the North Carolina Department of Agriculture and Consumer Services (NCDA & CS), where it continues today (Barker and Imbriani 1984).

By the turn of the twenty-first century, the peak of classical Nematology had passed. North Carolina State University altered its focus from classical Nematology to molecular research in order to remain progressive and competitive in a shifting science. C. Opperman was hired in 1987, E. L. Davis in 1993 and D. M. Bird in 1995, all of whom have made considerable contributions in nematode genomics, host-parasite relationships, transgenic host resistance and gene function. In 1986, S. R. Koenning was hired by NCSU to focus on nematode management and ecology on most field crops grown in North Carolina, including soybean, corn, cotton, and small grains.

The Nematode Assay Laboratory in the Agronomic Division of the NCDA & CS has been successively led by Nematologists D. A. Richard (1972–1979), J. L. Starr (1979–1981), Jack Imbriani (1981–2005) and Weimin Ye (2005 to present). It is now the largest nematode assay lab in the United States, processing 51,223 samples and issuing 6,498 reports in fiscal year 2018. Among those, 14,050 samples (1,378 reports) from many different states were specifically tested for the presence of pinewood nematode (*Bursaphelenchus xylophilus*) so that shipments of lumber and wood products could be cleared by United States Department of Agriculture – Animal and Plant Health Inspection Service – Plant Protection and Quarantine for export from the United States. In addition, a molecular diagnostic service was developed and implemented from 2011 to identify nematodes to the species level when this level of taxonomic resolution is needed.

In the State of North Carolina, nematodes are a major threat to most crops. About 82 plant parasitic nematode species have been recorded. Among them, root knot, soybean cyst, reniform, sting, lesion, lance, stubby root, tobacco cyst, ring, foliar, and stem and bulb nematodes are considered the most important and are the subjects in this chapter. The list of plant parasitic nematodes in Table 10.1 is based in part on the nematode section of the North Carolina Plant Disease Index by K. R. Barker (Grand 1985) and includes all recent research findings (Ye et al. 2012, 2013, 2015a, b; Ye 2017; Zeng et al. 2012b, 2015; Holguin et al. 2015a, 2016) and nematode

Table 10.1 Plant parasitic nematodes in North Carolina and South Carolina

Nematode species	State*	Crop or plant	References
Anguina tritici	NC, SC	Rye, wheat	Grand (1985)
Aorolaimus leipogrammus	SC	Bamboo	Sher (1963)
Aorolaimus spp.	NC	Camellia	Grand (1985)
Aphelenchoides fragariae	NC, SC	Ornamentals, strawberry	Williamson et al. (2000), McCuiston et al. (2007), Kohl et al. (2010), and Fu et al. (2012)
A. myceliophagus	NC	Mushrooms, turfgrass	Zeng et al. (2012b)
A. parietinus	NC, SC	Cotton	Steiner (1938) and Society of Nematologists (1984)
A. ritzemabosi	NC	Florist's daisy	Strider (1979) and Grand (1985)
A. subtenuis	NC, SC	Unknown	Society of Nematologists (1984)
Belonolaimus euthychilus	SC	Longleaf pine	Rau (1963)
B. gracilis	NC, SC	Corn, cotton	Graham and Holdeman (1953) and Ruehle and Sasser (1962)
B. longicaudatus	NC, SC	Bermuda grass, common bean, corn, cotton, creeping grasses, peanut, soybean, tomato	Lewis et al. (1993) and Zeng et al. (2012b)
B. maritimus	NC	American beachgrass	Grand (1985)
Cactodera weissi	NC	Bermuda grass, knotweed, tobacco	Grand (1985) and Ye (2012)
Criconema demani	SC	Unknown	Taylor (1936)
C. lamellatum	SC	Ferns, grass, trees	Raski and Golden (1966)
C. permistum	SC	Swamp soil	Raski and Golden (1966)
C. sphagni	NC	Trees	Ruehle (1968)
Criconemoides annulatus	SC	Unknown	Society of Nematologists (1984)
Crossonema fimbriatus	SC	Unknown	Mehta and Raski (1971)
Ditylenchus dipsaci	NC	Alfalfa, ornamentals, white clover, wild onion	Barker and Sasser (1959) and Grand (1985)
D. triformis	NC	Iris	Hirschmann and Sasser (1955)
Dolichodorus heterocephalus	NC, SC	Bermuda grass, camellia	Zeng et al. (2012b)
D. marylandicus	NC	Pine	Lewis and Golden (1981)
Globodera tabacum solanacearum	NC	Carolina horsenettle, tobacco	Melton et al. (1991)

(continued)

Table 10.1 (continued)

Nematode species	State*	Crop or plant	References
Helicotylenchus caroliniensis	SC	Swamp soil	Sher (1966)
H. dihystera	NC, SC	Bermuda grass, common bean, corn, cotton, creeping grasses, loblolly pine, peach, peanut, slash pine, soybean	Ruehle and Sasser (1962), Aycock et al. (1976), Schmitt and Barker (1988), Lewis et al. (1993), and Zeng et al. (2012b)
H. erythrinae	NC	Grass	Ruehle and Sasser (1962)
H. exallus	SC	Soybean	Nyczepir and Lewis (1979)
H. hydrophilus	SC	Swamp soil	Sher (1966)
H. microlobus	SC	Grass, strawberry	Perry et al. (1959)
Hemicaloosia graminis	NC, SC	Turfgrass	Zeng et al. (2012a)
Hemicriconemoides chitwoodi	NC, SC	Camellia, turfgrass	Ye and Robbins (2000), López et al. (2012a), and Zeng et al. (2012b)
H. wessoni	NC, SC	Bermuda grass	Ye and Robbins (2000) and Zeng et al. (2012b)
Hemicycliophora conida	NC, SC	Creeping bentgrass	Zeng et al. (2012b)
H. gigas	NC	Forest soil	Thorne (1955)
H. gracilis	NC	Grass	Thorne (1955)
H. mettleri	NC	Trees	Brzeski (1974)
H. parvana	NC	Turfgrass	López et al. (2013) and Van den Berg et al. (2018)
H. robbinsi	NC	Turfgrass	López et al. (2013), Subbotin et al. (2014), and Van den Berg et al. (2018)
H. sheri	NC	Grass	Society of Nematologists (1984)
H. thienemanni	SC	Turfgrass	Zeng et al. (2012b)
H. vaccinium	SC	Swamp soil	Brzeski (1974)
H. vidua	SC	Camellia	López et al. (2013)
Heterodera cyperi	NC	Ornamentals	Golden et al. (1962)
H. glycines	NC, SC	Common bean, soybean	Schmitt and Barker (1988) and Lewis et al. (1993)
H. lespedezae	NC	Bush clover	Golden and Cobb (1963)
H. trifolii	NC	Daylilly, white clover	Grand (1985) and Ye (2012)

(continued)

Table 10.1 (continued)

Nematode species	State*	Crop or plant	References
Hoplolaimus columbus	NC, SC	Cotton, slash pine, soybean	Ruehle and Sasser (1962), Sher (1963), Fassuliotis et al. (1968), Schmitt and Barker (1988), Lewis et al. (1993), and Holguin et al. (2015a, c, 2016)
H. galeatus	NC, SC	Bermuda grass, boxwood, Chinese holly, corn, cotton, creeping bentgrass, creeping grasses, slash pine, soybean, tall fescue, white clover	Schmitt and Barker (1988), Lewis et al. (1993), Martin et al. (1994), Zeng et al. (2012b), and Holguin et al. (2015a)
H. stephanus	NC	Soybean	Sher (1963) and Holguin et al. (2015a)
Longidorus breviannulatus	NC	Turfgrass	Society of Nematologists (1984)
L. crassus	SC	Turfgrass	Ye and Robbins (2005)
L. elongatus	SC	Unknown	Society of Nematologists (1984)
L. longicaudatus	SC	Unknown	Siddiqi (1962)
L. paralongicaudatus	SC	Turfgrass	Zeng et al. (2012b)
Meloidodera floridensis	NC	Azalea, grass, loblolly pine, slash pine	Ruehle and Sasser (1962), Triantaphyllou and Hirschmann (1973), and Ye (2012)
Meloidogyne arenaria	NC, SC	Asparagus, azalea, carrot, daylily, peanut, corn, sweet potato, tobacco, soybean, tomato	Tedford and Fortnum (1988), Lewis et al. (1993), and Agudelo et al. (2011)
M. carolinensis	NC	Blueberry	Eisenback (1982)
M. enterolobii	NC, SC	Cotton, horseweed, morning glory, sicklepod, soybean, sweet potato, tobacco	Ye et al. (2013) and Rutter et al. (2018)
M. graminis	NC, SC	Bermuda grass, blue oat grass, centipedegrass, creeping bentgrass, creeping grasses, meadow fescue, St. Augustine grass	Ye et al. (2015b) and Zeng et al. (2012b)

(continued)

Table 10.1 (continued)

Nematode species	State*	Crop or plant	References
M. hapla	NC, SC	Boxwood, cabbage, cantaloupe, common bean, cotton, gingseng, Irish potato, pea, peanut, peony, sage, soybean, strawberry, sweet potato, tobacco, tomato, watermelon, wheat	Schmitt and Barker (1988)
M. incognita	NC, SC	Alfalfa, asparagus, azalea, bean, begonia, bentgrass, bermuda grass, boxwood, Buddleja, butterbean, cabbage, camellia, cantaloupe, carrot, collards, common bean, corn, cotton, creeping bentgrass, creeping grasses, cucumber, daylily, dogwood, eggplant, English oak, fig, forsythia, gardenia, green bean, holly, hyacinth bean, hydrangea, kiwifruit, Korean boxwood, lantana, liriope, lima bean, mondo grass, milo, muskmelon, oak, okra, ornamentals, peach, pepper, peony, potato, pumpkin, sage, snap bean, soybean, spinach, squash, St. Augustine grass, strawberry, sweet potato, tobacco, tomato, tube rose, watermelon, white clover, zoysiagrass	Sitterly and Fassuliotis (1965), Schmitt and Barker (1988), Tedford and Fortnum (1988), Haygood et al. (1990), Lewis et al. (1993), and Agudelo et al. (2011)
M. javanica	NC, SC	Boxwood, southern peas, soybean, sweet potato, tobacco, tomato	Schmitt and Barker (1988)
M. marylandi	NC, SC	Bermuda grass, creeping bentgrass, creeping grasses	Ye et al. (2015b)
M. megatyla	NC	Loblolly pine	Baldwin and Sasser (1979)
M. naasi	NC, SC	Bermuda grass, creeping bentgrass, creeping grasses	Zeng et al. (2012b) and Ye et al. (2015b)
M. partityla	SC	Laurel oak	Eisenback et al. (2015)
M. spatinae	NC, SC	Smooth cordgrass	Rau and Fassuliotis (1965)
Mesoanguina plantaginis	NC, SC	Bracted plantain	Vargas and Sasser (1976)
Mesocriconema curvatum	NC, SC	Bermuda grass, creeping bentgrass, creeping grasses, soybean	Lewis et al. (1977, 1993) and Zeng et al. (2012b)
M. ornatum	NC, SC	Corn, blueberry, grasses, ornamentals, peanut	Ratanaworabhan and Smart Jr. (1970), Schmitt and Barker (1988), Powers et al. (2014), and Jagdale et al. (2013)

(continued)

Table 10.1 (continued)

Nematode species	State*	Crop or plant	References
M. rusticum	SC	Unknown	Society of Nematologists (1984)
M. sphaerocephalum	NC, SC	Corn, peanut	López et al. (2012b) and Zeng et al. (2012b)
M. xenoplax	NC, SC	Bermuda grass, Chinese holly, creeping bentgrass, ornamentals, peach	Aycock et al. (1976), Nyczepir et al. (1985), Zeng et al. (2012b), and Powers et al. (2014)
Nanidorus minor	NC, SC	American holly, azalea, bentgrass, bermuda grass, boxwood, camellia, centipedegrass, Chinese holly, corn, cotton, creeping bentgrass, holly, loblolly pine, longleaf pine, ornamentals, peach, peanut, slash pine, soybean, tall fescue, tobacco, white clover	Schmitt and Barker (1988), Lewis et al. (1993), Boutsika et al. (2004), Zeng et al. (2012b), and Huang et al. (2018)
Ogma decalineatum	SC	Ferns	Mehta and Raski (1971)
O. floridense	NC, SC	Bermuda grass	Zeng et al. (2012b)
Paratrichodorus allius	NC, SC	Creeping bentgrass	Zeng et al. (2012b)
P. porosus	NC, SC	Camellia, corn, sorghum, soybean	Huang et al. (2018)
Paratylenchus goldeni	NC	Boxwood, centipedegrass	Zeng et al. (2012b)
Pratylenchus brachyurus	NC, SC	Cotton, peach, peanut, soybean, tobacco	Schmitt and Barker (1988) and Lewis et al. (1977, 1993)
P. coffeae	NC, SC	Peach	Grand (1985)
P. macrostylus	NC	Fraser fir, red spruce	Hartman and Eisenback (1991)
P. penetrans	NC, SC	Bermuda grass, boxwood, peach, potato, soybean, tobacco	Grand (1985) and Zeng et al. (2012b)
P. pratensis	NC	Cotton, ornamentals, potato, tobacco	Steiner (1938) and Grand (1985)
P. scribneri	NC, SC	Common bean, peach, soybean, tobacco	Grand (1985) and Lewis et al. (1993)
P. vulnus	NC	Boxwood, Chinese holly, peach	Grand (1985)
P. zeae	NC	Corn, peach, tall fescue	Grand (1985) and Schmitt and Barker (1988)
Quinisulcius capitatus	NC	Unknown	Society of Nematologists (1984)

(continued)

Table 10.1 (continued)

Nematode species	State*	Crop or plant	References
Rotylenchulus reniformis	NC, SC	Cotton, sweet potato	Grand (1985), Lewis et al. (1993), Koenning et al. (2004), Leach et al. (2012), and Holguin et al. (2015b)
Rotylenchus buxophilus	NC	Azalea, boxwood	Grand (1985)
R. pumilus	NC	Trees	Ruehle (1968)
Scutellonema brachyurus	NC, SC	Bermuda grass, corn, cotton	Kraus-Schmidt and Lewis (1979), Lewis et al. (1993), Agudelo and Harshman (2011), and Zeng et al. (2012b)
Trichodorus elefjohnsoni	NC	Tulip poplar	Bernard (1992)
T. obtusus	NC, SC	Bermuda grass, St. Augustine grass, zoysiagrass	Shaver et al. (2013, 2015, 2016), Ye et al. (2015a, b), and Huang et al. (2018)
Trophurus sculptus	SC	Ferns, grass, hardwood trees	Society of Nematologists (1984)
Trophurus spp.	NC	Azalea	Grand (1985)
Tylenchorhynchus claytoni	NC, SC	American holly, azalea, bermuda grass, camellia, centipedegrass, Chinese holly, common bean, corn, cotton, creeping bentgrass, lima bean, loblolly pine, longleaf pine, ornamentals, peach, peanut, potato, slash pine, soybean, strawberry, tall fescue, tobacco, tomato, white clover	Steiner (1937), Ruehle and Sasser (1962), and Aycock et al. (1976), Schmitt and Barker (1988), Lewis et al. (1993), and Zeng et al. (2012b)
T. maximus	NC	Grasses, tomato	Grand (1985)
Tylenchulus sp.	SC	Peach	Wehunt et al. (1987)
Xenocriconemella macrodora	NC	Boxelder maple	López et al. (2012a)
Xiphinema americanum sensu lato	NC, SC	American holly, azalea, bermuda grass, boxwood, centipedegrass, Chinese holly, corn, cotton, loblolly pine, ornamentals, peach, peanut, slash pine, soybean, strawberry, sweet potato, tall fescue, tobacco, tomato	Ruehle and Sasser (1962), and Zeng et al. (2012b)
Xiphinema bakeri	NC	Bermuda grass	Zeng et al. (2012b)
Xiphinema chambersi	NC, SC	Azalea, bermuda grass, centipedegrass, ornamentals, rose, soybean	Ye (2012) and Zeng et al. (2012b)
Xiphinema krugi	NC	Bermuda grass, boxwood, cotton, ornamentals, soybean, tomato	Ye and Robbins (2010)

*Names of the states are represented by two letter abbreviations: NC North Carolina, SC South Carolina assay services provided by the NCDA & CS. Nematode entries in this list do not necessarily indicate that all nematodes associated with a given plant species are pathogenic to that plant species. Although all these nematodes are obligate parasites, some of them often cause little or no damage. Furthermore, nematodes are primarily soil inhabitants and may feed on associated weeds and grasses. In a few instances, the nematodes included under a given plant species probably were feeding primarily on these associated plants/weeds or had fed on previous crops.

South Carolina is bordered to the north by North Carolina with similar climate and agricultural crops and thus should harbor similar nematode species (Alexander 1963; Lewis et al. 1993; Dickerson et al. 2000; Zeng et al. 2012a, b; Shaver et al. 2013; Holguin et al. 2015a, c, 2016; Mueller and Agudelo 2015; Ye et al. 2015a). There are many reports of plant nematodes in South Carolina published by Prof. S. A. Lewis and Prof. P. Agudelo from the Clemson University. So far, 105 plant nematodes were recorded in the Carolinas (Table 10.1), but only 41 species were recorded in both states. Some of the species were never recorded in either North Carolina or South Carolina but may very likely have been omitted due to lack of study and are still present in another state.

10.2 Root Knot Nematodes, *Meloidogyne* spp.

The most common plant parasitic nematodes identified in North Carolina are the root knot nematodes (*Meloidogyne* spp.) (Meadows et al. 2018). These pests can be a serious problem for most field crops, vegetables, fruit trees, turfgrasses and ornamental plants especially in sandy soil. Infected plants are stunted and pale, drop flowers and fruits, wilt often, and decline even when plants are generously watered and fertilized. Growers most often realize they have root knot nematode at the end of the season, when they are pulling up spent crops and notice multiple bumpy, knot-like swellings on the roots of plants. Concomitant infection of roots galled by *Meloidogyne* spp. by other soilborne pathogens occurs frequently and increases the decline of host plant vigor and productivity. Currently, there are 11 species recorded in North Carolina, including *Meloidogyne arenaria, M. carolinensis, M. enterolobii, M. graminis, M. hapla, M. incognita, M. javanica, M. marylandi, M. megatyla, M. naasi* and *M. spatiniae.* Three tropical species (*M. incognita, M. javanica* and *M. arenaria*) and temperate species (*M. hapla*) are the predominant species and cause major damage to plants in this state.

10.2.1 Meloidogyne enterolobii

Meloidogyne enterolobii is a recently detected and emerging species causing severe damage to sweet potato, soybean, cotton and tobacco (Ye et al. 2013). It is believed to be an introduced species only confirmed in Columbus, Greene, Harnett, Johnston,

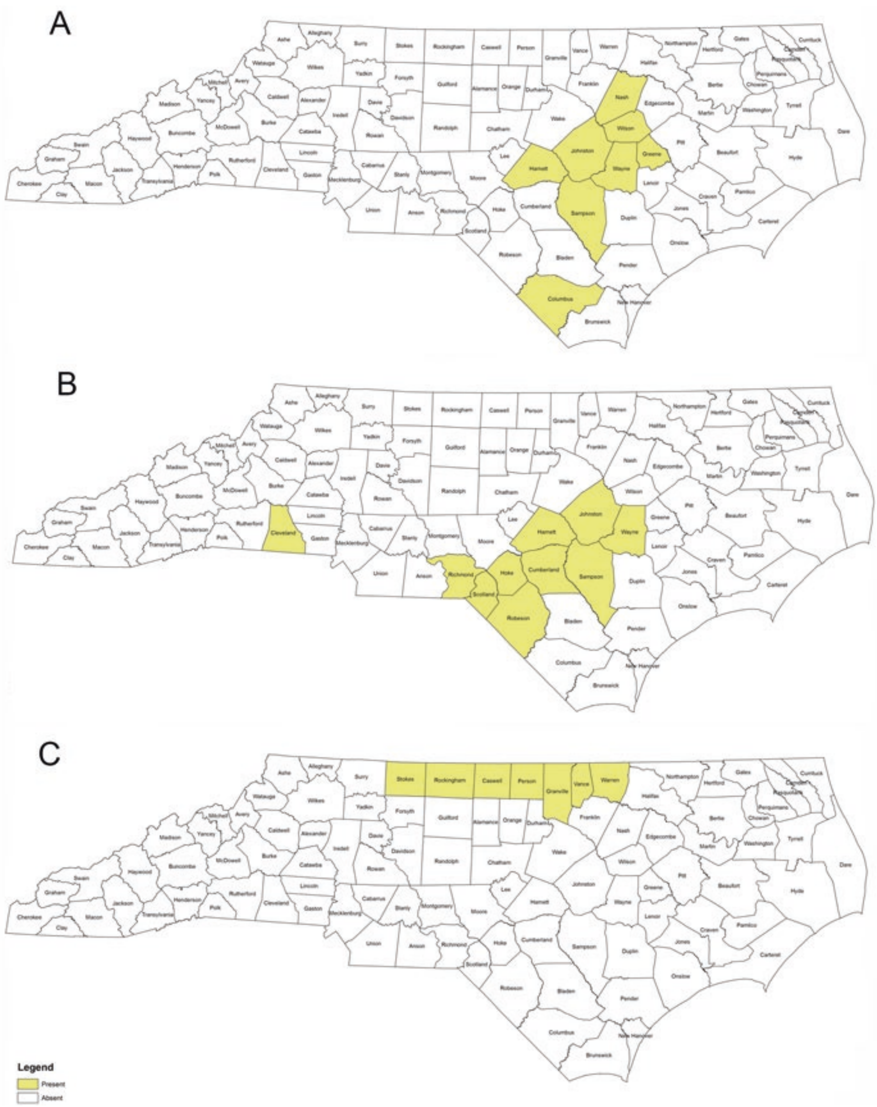

Fig. 10.1 Distribution of three plant parasitic nematodes in North Carolina as of September 2018 (yellow color counties): (**a**) *Meloidogyne enterolobii;* (**b**) *Rotylenchulus reniformis;* (**c**) *Globodera tabacum*

Nash, Sampson, Wayne and Wilson Counties in North Carolina as of September 2018 (Fig. 10.1a). It has a wide host range, including field crops and weeds. This species is a major concern to sweet potato growers because it affects not only the yield, but also the quality of sweet potato (Fig. 10.2). Once infested, the nematode

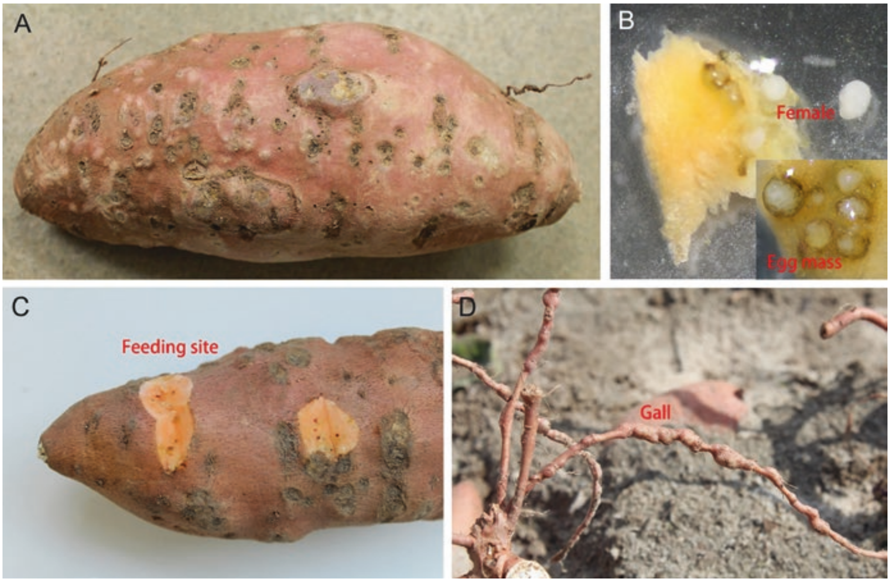

Fig. 10.2 Symptoms of sweet potato caused by *Meloidogyne enterolobii* in North Carolina. (**a**, **c**) Infected sweet potato; (**b**) Female and an egg-mass; (**d**) Galls

often causes total crop loss and sweet potatoes are not marketable. *Meloidogyne enterolobii* is a tropical species that was recorded only from Florida in the United States (Brito et al. 2004) until recently from field crops in North Carolina (Ye et al. 2013). *Meloidogyne enterolobii* was originally described from a population collected from the pacara earpod tree (*Enterolobium contortisiliquum*) in China in 1983. In 2001, it was detected for the first time in the continental United States in South Florida from regulatory samples of ornamental plants. *Meloidogyne enterolobii* is now considered one of the most important root knot nematode species because of its ability to reproduce on root-knot-nematode-resistant (*Mi-1, Mh, Mir1, N, tabasco*, and *Rk* gene carrying genotypes) crops. The greenhouse bioassay revealed this species could cause galls on the North Carolina differential hosts of tomato, bell pepper, tobacco, water melon, cotton, but not on peanuts, and has the same differential plant hosts as southern root knot nematode (*Meloidogyne incognita*) race 4 (Ye et al. 2013). There are no resistant varieties available against this root knot nematode species and the use of soil fumigation before planting and use nematode-free transplants are recommended. This introduced species is having a significant impact on North Carolina agriculture and poses a threat to sweet potato and other crop hosts if it is not controlled.

10.2.2 Other Meloidogyne *Species*

Meloidogyne marylandi, M. graminis and *M. naasi* are limited to turfgrass in North Carolina (Ye et al. 2015b; Zeng et al. 2012b, 2015). *Meloidogyne marylandi* and *M. graminis* are widely distributed in the state and cause damage to turfgrass, whereas *M. naasi* has limited distribution and damage in turfgrasses. Blueberry root knot nematode, *M. carolinensis,* was described from cultivated highbush blueberry (cultivars derived from hybrids of *Vaccinium corymbosum* and *V. lamarckii*) in Rose Hill, Duplin County, North Carolina (Eisenback 1982). Host range studies showed that only blueberry (*Vaccinium* sp.) and azalea (*Rhododendron* sp.) were good hosts. *Meloidogyne megatyla* (Baldwin and Sasser 1979) was described from loblolly pine (*Pinus taeda*) in Bladen County, North Carolina and has a host range that is different from other *Meloidogyne* species. *Meloidogyne spartinae* was originally described as *Hypsoperine spartinae* (Rau and Fassuliotis 1965). However, the genus *Hypsoperine* was synonymized and two of its species were renamed as *M. graminis* and *M. spartinae* (Whitehead 1968; Plantard et al. 2007).

Root knot nematodes are very difficult to manage because they are soilborne pathogens with a wide host range. The most reliable control of root knot nematodes can be achieved by integrating two or more control tactics. Combining an effective non-host rotation, resistant varieties, and selected cultural practices can give excellent control with little added cost. Crop rotation is one of the oldest and most economical methods of controlling nematodes. Rotation is simply the practice of not growing a susceptible host in the same site for more than 1 year. Nonhost plants that are especially suitable for rotation in root knot-infested fields include fescue, small grains, marigolds, sweet corn, asparagus and cool season crops in the cabbage family such as broccoli, kale, collards and mustard. Cultural methods may minimize root knot nematode damage. Practices such as removing the roots of each crop as soon as harvest is completed, followed by tilling the soil two to three times is very effective in reducing nematode levels, followed by a winter cover crop of annual rye grass, rye or wheat. Maintaining optimum conditions for plant growth in terms of soil pH, fertility, and soil moisture will increase the tolerance of low to moderate nematode pressure and will make the plants less susceptible to other stresses as well. Frequent incorporation of organic matter, especially high rates of composted leaves and manure into the soil is also beneficial for improving soil structure and moisture retention. It also encourages natural enemies in the soil for biological control of the nematodes. In some situations, nematode severity is sufficiently high so that chemical control is the only effective option. Fumigants are commonly applied as pre-plant treatments to reduce nematode numbers, but they must thoroughly penetrate large soil volumes to be effective. Nonfumigant and systemic compounds are less effective, but they have some advantage in ease of application and handling.

10.3 Soybean Cyst Nematode, *Heterodera glycines*

Soybean cyst nematode (SCN), *Heterodera glycines*, is an obligate and sedentary plant parasitic species that is the number one pathogen of soybean, causing more than twice as much yield loss than any other disease (Allen et al. 2017). SCN was first discovered in the United States in New Hanover County, North Carolina, in 1954 (Winstead et al. 1955) and is believed to have been introduced from Asia (Riggs 2004). SCN distribution in the United States has spread rapidly, although the underlying cause is debated. By 2017, SCN was found in every soybean-producing state in the United States except for West Virginia (Tylka and Marett 2017).

The Agronomic Division of NCDA & CS has analyzed numerous soil samples to monitor the spread and distribution of SCN. From July 1, 2014 to June 30, 2017, 100,118 soil samples were submitted for routine nematode assay by growers of various crops in 97 North Carolina counties. Only Alleghany, Clay, and McDowell Counties were not represented in this sample population. SCN was detected in 21,922 of the soil samples (21.9%) (Ye 2017). The overall mean population density of the second-stage juveniles and females was 110 ± 266 (10–14,600) per 500 cm^3 of soil. The total of SCN-positive counties included 57 counties in North Carolina (Fig. 10.3). Catawba is the only county not shown on the recent North American SCN distribution map published by Tylka and Marett (2017). Johnston (3462 SCN-positive samples), Wayne (3274), Nash (2960), Wilson (2039), and Pasquotank (1513) counties had the most SCN-positive samples. Population density (the second-stage juveniles and females of SCN/500 cm^3 of soil in average) were highest in Montgomery (831), Bladen (790), Washington (610), Carteret (607), and Harnett (368) Counties. According to the most recent NCDA & CS data of soybean-planted fields and yield statistics by county in North Carolina (NCDA Agricultural Statistics 2017), soybean is mainly grown in the eastern half of the state. In general, the SCN-negative counties are those with no soybean acreage or less than 200 planted hectares of soybeans in the western part of the state. The high number of samples in this

Fig. 10.3 Known distribution of SCN in North Carolina as of September 2018 (green counties) and average SCN population density (number of the second-stage juveniles and females of SCN/500 cm^3 soil) from each county

work gave a clear picture of where SCN is occurring in North Carolina and its population density in each county since its first detection in the United States in 1954. Given the yield losses that SCN is capable of causing, SCN continues to be a yield-limiting factor in the state, and growers should be actively managing this obligate parasite to mitigate yield loss.

To reduce the crop losses caused by SCN, an integrated management approach using multiple practices is recommended. Managing reproduction by using soybeans with an earlier maturity group can help reduce population numbers the following year. Crop rotation with nonhost crops such as corn, cotton, tobacco, sweet potato, peanuts or sorghum is very effective in decreasing SCN populations. The use of resistant varieties gives excellent control. Resistant varieties can only be used effectively when matched with the correct SCN race. The continued use of the same resistant variety can lead to a race shift in the population (Koenning 2004). Field populations of SCN have historically been characterized as races 1–16 based on four soybean hosts (Riggs and Schmitt 1988); however, these are now characterized as HG types based upon source of SCN resistance (Niblack et al. 2002). A study by NCDA & CS and North Carolina Cooperative Extension Agents of soybean cyst populations was conducted to determine the most abundant races in North Carolina using the old SCN race system (Riggs and Schmitt 1988). Of the 18 counties sampled in 2017, races 2 (87%), 4 (10%), and 5 (3%) were identified. Few varieties have resistance to the races recently identified in North Carolina. Some of the varieties that have resistance to SCN races 2, 4 or 5 include: Fowler (Race 1,2,3,5,14), Jake (1,2,3,5,14), JTN-5503 (2,3,5,14), N7003CN (1,2,3,4,5,14), Osage (2,3,14), and P52T86R (1,2,3,5,14) (Joyce and Thiessen 2017). Chemical controls for SCN are often expensive and do not guarantee a positive yield response, and few nematicides are registered for use against SCN. The fumigant 1,3-dichloropropene (Telone II) can be used for SCN control (Thiessen 2018). Seed treatments using *Pasteuria nishizawae* (Clariva), abamectin (Avicta), *Bacillus fermis* (Poncho/Votivo), fluopyram (Ilevo) are recommended in managing yield losses when used in fields with low to moderate populations of SCN (Thiessen 2018). Seed treatments may help soybean plants establish larger root volume but provide a short window of efficacy since they treat a small volume of soil/roots. These should be used in conjunction with other management practices described above.

10.4 Reniform Nematode, *Rotylenchulus reniformis*

Reniform nematode, *Rotylenchulus reniformis,* has been recorded only from Cleveland, Cumberland, Harnett, Hoke, Johnston, Richmond, Robeson, Sampson, Scotland and Wayne Counties in North Carolina (Fig. 10.1b). This species is semi-endoparasitic in which the females penetrate the root cortex, establish a permanent feeding site in the stele region of a root and become sedentary or immobile. The anterior portion of the female body remains embedded in the root, whereas the posterior portion protrudes from the root surface and swells during maturation. It is only considered hazardous to cotton, soybean and sweet potato in North Carolina. Corn and peanuts are very poor hosts and small grains, sorghum and common bermudagrass are nonhosts. Management includes fallow, rotation with nonhost or poor host crops, nematicides and weed control. Crop rotation with resistant or immune plant species is recommended. These include mustard (*Brassica nigra*), oats, rhodesgrass (*Chloris gayana*), onion and sun hemp (*Crotalaria juncea*) (Robinson et al. 1997; Caswell et al. 1991). Sorghum, corn and reniform nematode resistant soybeans are recommended as rotation crops for cotton (Starr and Page 1990; Starr et al. 2007).

10.5 Sting Nematode, *Belonolaimus longicaudatus*

Belonolaimus longicaudatus was originally described from soil around the roots of corn in Sanford, Florida (Rau 1958). It is a major plant parasite in the sandy soils in Southeastern United States, with widespread distribution throughout the Atlantic Coastal Plain from Virginia to Florida (Lucas et al. 1974; Orton Williams 1974). It is considered the most important pest of turf and pasture grasses (Heald and Perry 1970; Crow 2005). While this species has been documented in association with many grass species, in a survey, *B. longicaudatus* was found in 131 turfgrass samples in three turf management zones (green, fairway and tee) in both North Carolina and South Carolina and three grass species (bermudagrass, creeping bentgrass, zoysiagrass) from 24 counties (Zeng et al. 2012b). In addition to turfgrasses and home owner lawns, this nematode causes considerable damages to cotton, corn, peanuts, soybean and strawberry in North Carolina, but it is restricted to sandy soil.

Sting nematodes can be effectively managed with nematicides. Unlike many of the endoparasitic nematodes that spend a majority of their life within roots, contact nematicides often work well on sting nematode. 1,3-dichloropropene (Curfew), abamectin (Avid) 0.15 EC, abamectin (Divanem) 0.7 SC, *Bacillus firmus* (Nortica), fluensulfone (Nimitz Pro G), fluopyram (Indemnify) and furfural (Multiguard Protect) are currently registered and can be effectively used to reduce sting nematode populations (Kerns and Butler 2018). Nortica is a bacterial biological control agent, *Bacillus firmus,* used for the protection of plant roots against plant parasitic nematodes in several crop species. On turfgrasses, relieving additional stresses by raising mowing height, increasing irrigation frequency, improving aeration to roots, and reducing traffic can improve tolerance to sting nematodes. The addition of organic, and some inorganic, amendments to soil also can improve tolerance to sting nematodes by improving the water and nutrient-holding capacity of the soil (Crow and Han 2005).

10.6 Lesion Nematodes, *Pratylenchus* spp.

The lesion nematodes of the genus *Pratylenchus* are recognised worldwide to have a great economic impact in crop production. This is not only due to their wide host range, but also their distribution in almost every temperate and tropical environment. At present, more than 80 species of *Pratylenchus* have been described, with a combined host range of greater than 400 crop plant species (Loof 1991; Castillo and Vovlas 2007). The species recorded in North Carolina include *P. brachyurus, P. coffeae, P. macrostylus, P. penetrans, P. pratensis, P. scribneri, P. vulnus* and *P. zeae*. These migratory endoparasites of plants mainly feed and move within plant roots. Crops of primary economic importance that are attacked by lesion nematodes include potato, corn, cotton, soybean, tobacco, peanuts, forage legumes, ornamental plants and many fruit trees. Symptoms of lesion nematode disease often go unrecognized initially because the nematodes are microscopic pathogens of belowground plant parts (mainly roots), and the aboveground symptoms are often general symptoms of plant-root stress. Lesion nematodes induce characteristic necrotic lesions (darkened areas of dead tissue) on the surface and throughout the cortex of infected roots. The lesions turn from reddish-brown to black and are initially spotty along the root surface. As the nematodes continue to migrate and feed within the roots, the lesions can coalesce to become large necrotic areas of tissue that may eventually girdle the root. The wounds inflicted on plant roots and other below ground plant parts by lesion nematodes can serve as infection courts for pathogenic soil microbes, primarily fungi. This causes disease complexes that involve lesion nematodes and wilt fungi such as *Fusarium* and *Verticillium* (Rowe et al. 1987; MacGuidwin and Rouse 1990).

Lesion nematodes are difficult to control. Cultivars bred for resistance to lesion nematodes are not currently commercially available. Rotations to nonhost crops offer limited opportunities to manage lesion nematode field populations since most *Pratylenchus* species have wide host ranges. If the species of *Pratylenchus* is accurately diagnosed, and a suitable economic nonhost can be grown, rotations offer some promise as a management practice. The two most effective tactics for lesion nematode management remain sanitation and the use of nematicides.

10.7 Lance Nematodes, *Hoplolaimus* spp.

Columbia lance nematode, *Hoplolaimus columbus*, was first described from soybean in Richland County, South Carolina (Sher 1963). Since that time, *H. columbus* has been found mainly in South Carolina, North Carolina, and Georgia (Lewis and Fassuliotis 1982; Koenning et al. 1999; Holguin et al. 2015a, 2016). It is primarily associated with cotton and soybean and has limited distribution in North Carolina (Fig. 10.4). Losses to *H. columbus* in cotton are typically 10–25% and on soybean as high as 70% (Mueller and Sanders 1987; Noe 1993). *Hoplolaimus columbus* is

Fig. 10.4 Known distribution of *Hoplolaimus columbus* in North Carolina as of September 2018 (yellow color counties)

the predominant species associated with soybean in South Carolina, whereas another lance species *H. stephanus* was the prevalent species in North Carolina (Holguin et al. 2015a, 2016). The Columbia lance nematode feeds both externally and internally on soybean roots. Lesions may develop on roots which can coalesce and give the appearance of root rot. The amount of damage to soybean and subsequent yield loss will be directly proportional to the soil population density of this nematode at soybean planting. Corn, cotton and soybean are good hosts for this nematode. Nematode densities are generally in the moderate to high range following these crops. Peanuts, tobacco and small grains are poor or nonhosts for Columbia lance nematode.

Hoplolaimus galeatus was first described from soil in Virginia (Cobb 1913). In a survey, *H. galeatus* was found from 22 counties in North Carolina and South Carolina (Zeng et al. 2012b). It feeds and reproduces on a wide range of plant hosts and can cause serious damage to cotton (Krusberg and Sasser 1956; Wrather et al. 1992; Martin et al. 1994; Gazaway and Mclean 2003), soybean (Lewis et al. 1993), and corn (Norton and Hinz 1976). It is also considered an economically important pest of turfgrasses such as St. Augustine grass (*Sternotaphrum secundatum*) and bermudagrass (*Cynodon dactylon*) (Henn and Dunn 1989; Giblin-Davis et al. 1995), but is considered to be a moderate damaging species in North Carolina.

10.8 Stubby Root Nematodes, *Nanidorus minor* and *Trichodorus obtusus*

Stubby root nematode, *Nanidorus minor*, is a common and widespread nematode in North Carolina. They feed primarily on meristem cells of root tips causing a stunted or "stubby" appearing root system (Fig. 10.5). *Nanidorus minor* is important because of the direct damage to plant roots and also transmitting specific plant

Fig. 10.5 (**a**) Stubby-root nematode, *Nanidorus minor*; (**b**) Stubby root symptom caused by *Nanidorus minor* on corn from Bladen County in North Carolina

tobraviruses (Decraemer 1995). Stubby root nematodes are migratory, ectoparasitic and obligate plant parasites that feed on plants while their bodies remain in the soil. *Nanidorus minor* is a parthenogenic species and reproduces without sexual activity; males are rare. The life cycle of *P. minor* is fairly short for a plant parasite, being as short as 16 days at 29 °C. Stubby root nematode is considered a serious pest on corn, cotton, azalea and turfgrass in North Carolina. In a survey conducted in North Carolina and South Carolina, *N. minor* was found in 121 turfgrass samples taken in 33 counties (Zeng et al. 2012b).

Another stubby-root nematode, *Trichodorus obtusus*, was recently identified from South Carolina from 'Tifway' Bermudagrass (*Cynodon dactylon* × *C. transvaalensis*), 'Emerald' Zoysia (*Zoysia japonica*), 'Empire' Zoysia (Shaver et al. 2013) and from North Carolina from bermudagrass, St. Augustinegrass (*Stenotaphrum secundatum*) and Zoysiagrass (Ye et al. 2015a). This species is clearly different from the parthenogenic *Nanidorus minor* because of the presence of males, larger body sizes and DNA sequences of ribosomal DNA near-full-length small subunit (18S) and large subunit domain 2 and 3 (28S D2/D3). *Trichodorus obtusus* is known to occur only in the United States and damages turfgrasses. It is reported in the states of Virginia, Florida, South Carolina, Texas, Iowa, Kansas, Michigan, New York, North Carolina and South Dakota (Crow and Welch 2004; Shaver et al. 2013; Ye et al. 2015a).

10.9 Tobacco Cyst Nematode, *Globodera tabacum*

The tobacco cyst nematode, *Globodera tabacum*, is a serious and important soil-borne parasite of the tobacco roots. The species comprises three subspecies: *G. t.* subsp. *tabacum*, *G. t.* subsp. *solanacearum* and *G. t.* subsp. *virginiae*. These subspecies are differentiated by host preference. *G. t.* subsp. *tabacum* parasitizes shade-grown cigar wrapper and fieldgrown broadleaf cigar tobacco (*Nicotiana tabacum*) (Lownsbery and Peters 1955); *G. t.* subsp. *virginiae*, the horsenettle nematode, does not reproduce well in *Nicotiana* species (Miller 1977); and *G. t.* subsp. *solanacearum* attacks flue-cured tobacco cultivars (Komm et al. 1983). Only *G. t.* subsp. *virginiae* and *G. t.* subsp. *solanacearum* were found in North Carolina (Shepherd and Barker 1990; Melton et al. 1991). *Globodera tabacum solanacearum* was reported in North Carolina for the first time in 1991 in flue-cured tobacco fields in Warren County (Melton et al. 1991), but it is now distributed in Caswell, Granville, Person, Rockingham, Stokes, Vance and Warren Counties adjoining the Virginia border (Fig. 10.1c). Infection of the tobacco root system by tobacco cyst nematodes causes dramatic stunting, yield loss and decreases leaf quality. The use of resistant crops is useful in an integrated pest management program for controlling tobacco cyst nematode (Herrero et al. 1996).

Long-term control of any cyst nematode is difficult as viable eggs within cysts can survive in the soil for many years. Methods used include trap cropping, early destruction of roots and stalks, chemical control, crop rotation and the use of resistant tobacco genotypes.

10.10 Ring Nematodes, *Mesocriconema* spp.

Ring nematodes are very common, widespread and often occur at high population densities. However, symptoms of injury are not consistently associated with high numbers of this nematode and they are not often pathogenic. Plants which often support high populations of ring nematodes include peach, peanut and turfgrass in North Carolina.

The ring nematode, *Mesocriconema xenoplax*, is one of the most important nematode pathogens on peach due to its association with the disease complex known as Peach-Tree-Short-Life (PTSL) disease complex (Barker and Clayton 1973; Brittain and Miller 1978; Nyczepir et al. 1985; Parker 2000). Infection of ring nematodes can cause peach trees to be more susceptible to bacterial canker and cold damage, thus vastly reducing peach yields. PTSL is apparent in the spring when trees, or portions of trees, fail to grow. Trees, especially ones in their third to sixth season, may be killed back to the soil line. This problem most often occurs where trees are replanted in recent peach tree sites. Although nematodes rarely kill trees, they can predispose them to PTSL, especially ring nematodes. Cultivars tolerant to PTSL include ‘Guardian’ (root knot resistant), ‘Lovell’ (root knot susceptible) and ‘Halford’. The root knot resistant cultivar ‘Nemaguard’ is very susceptible to

PTSL. The root knot resistant cultivar 'Guaradian' is a good choice for management of PTSL, but pretreatment of infested planting sites with a nematicide is needed to control nematodes and limit PTSL. Long-term cropping systems should also be considered in peach tree establishment and PTSL management. Successful management strategies may include use of cover crops such as bermudagrass or wheat.

Ring nematodes commonly infest golf course turfgrasses throughout the United States. High numbers of ring nematodes can cause visual chlorosis and decline of turfgrasses, particularly on putting greens. The above-ground symptoms of nematode feeding are slow growth, thinning of the turfgrass, poor response to adequate fertilization and irrigation, rapid wilting during dry weather, and weed invasion. These symptoms typically appear as irregular patterns across the turfgrass stand, not in circular patches or other distinct patterns. By the time above-ground symptoms of ring nematode injury appear, significant damage to the root system may have already occurred. There are three species of ring nematodes, *M. xenoplax, M. curvatum* and *M. sphaerocephalum,* that are known to damage turfgrasses in North Carolina (Ye et al. 2012; Zeng et al. 2012b).

Peanut ring nematode, *Mesocrionema ornatum*, commonly infects roots of peanut plants but has low damage potential. It is known to occur in a large percentage of the peanut production regions of the United States (Wheeler and Starr 1987; Dickson and De Waele 2005). It caused "yellows disease' symptom in microplots studies of several crops that used freshly-extracted, greenhouse-grown inoculum of *M. ornatum* (Barker et al. 1982). Greenhouse studies in North Carolina reavealed an interaction between *M. ornatum* and the black rot fungus *Cylindrocladium crotalariae* (Diomande and Beute 1981a, b).

10.11 Foliar Nematode, *Aphelenchoides fragariae*

Foliar nematodes (*Aphelenchoides* spp.) are an emerging problem on a number of landscape plant species in North Carolina, with *Aphelenchoides fragariae* as the predominant species detected. Unlike many other plant shoot pathogens that have narrow host ranges, foliar nematodes have broad host ranges and are capable of infecting hundreds of species of agronomic and ornamental plants including numerous ferns, foliage and flowering plants, and herbaceous and woody perennials (Decker 1989; Daughtrey et al. 1995; Knight et al. 1997, 2002). They live in the aboveground portions of plants, often without causing any obvious symptoms. The nematodes can remain on the outside of the plant, but most penetrate into leaf and stem tissue. Wetness on the stems and leaves provides an excellent environment for their movement. Splashing water during irrigation readily spreads the nematodes from leaf to leaf and plant to plant. Optimum temperatures for foliar nematode development are between 21 and 24 °C. The entire life cycle can be completed in 2–4 weeks, even sooner if the temperatures are higher. The most practical and effective control strategy is early detection and exclusion of this pest from growing facilities, including the use of nematode-free propagative stock.

10.12 Stem and Bulb Nematode, *Ditylenchus dipsaci*

Stem and bulb nematode, *Ditylenchus dipsaci*, is an endoparasitic migratory nematode that attacks aerial parts, bulbs and tubers of plants, causing the breakdown of the middle lamellae of cell walls. Feeding often causes swellings and distortion of aerial plant parts (stems, leaves, flowers) and necrosis or rotting of stem bases, bulbs, tubers and rhizomes. During cold storage of bulbs and tubers, *D. dipsaci* and related rotting may continue to develop. *Ditylenchus dipsaci* occurs locally in most temperate areas of the world and is occasionally found in ornamental plants in North Carolina (Fig. 10.6). A recent severe infestation on onion in Craven County in North Carolina revealed the presence of a species of *Ditylenchus*, but not *D. dipsaci* according to DNA sequencing data (Ye unpublished).

In most countries, regulatory measures such as certification schemes are applied to minimize further spread of *D. dipsaci*. However, North Carolina does not have a seed certification program. Bulbs and seeds can be disinfected by hot-water treatments. Races of *D. dipsaci* are highly host-specific, so employing a 3-year crop rotation can deprive the nematodes of a suitable host and starve the population. *Ditylenchus dipsaci* is known to attack over 450 different plant species, including many weeds (Hooper 1972). The use of tolerant or resistant cultivars can also reduce the damage. Soil fumigation in fields during fall can control nematodes on a susceptible crop in the spring.

Fig. 10.6 Photographs of symptoms caused by *Ditylenchus dipsaci* on *Hydrangea macrophylla* from Johnston County in North Carolina (**a**); *D. dipsaci* dults and juveniles (**b**) (lab ID: 14–38639)

10.13 Conclusion and Future Perspectives

Agriculture will continue to be the number one industry in the State of North Carolina and farmers will continue to fight against plant parasitic nematodes to increase crop production. Root knot nematodes are most common and destructive in this state due to their wide host range and wide distribution. In the past few years, *Meloidogyne enterolobii* has become an emerging species damaging several field crops, especially to sweet potato due to its severe damage on the storage roots resulting in unmarketable products and sometimes total loss. Soybean cyst nematode is still expanding in distribution posing a very serious threat to soybean production in North Carolina. Nematodes are microscopic hidden enemies of plants that are often difficult to detect, therefore, using nematode advisory service through state lab has been encouraged to determine the presence of nematode species, population density, hazard level and management action. New molecular diagnosis tool can be used to detect new emerging and or existing nematode species. Novel nematode management strategies should be developed, including more effective nematicides and resistant varieties to facilitate the reduction of crop losses to nematode damage.

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