Nematodes

In the six decades since the first edition of this book was prepared, nematodes have become of major importance in plant pathology. It used to be stated that plant pests, insects, and diseases, took a toll of one-tenth of all our crops. Now we believe that nematodes alone may cause a 10 % crop loss, and some place the figure as high as 25 %. The monetary loss is not easy to figure. Guesses range from $500,000 to $8 billion a year in the U. S. Nematodes may be as damaging in home gardens as on farms.

Nematodes used to be considered primarily a southern problem, with the root-knot nematode the major culprit. Now we know that nematodes can be as serious in Maine or Minnesota as in Florida or Texas, and that root-knot species are responsible for only a fraction of total losses.

A 1957 report from Maryland states that samples were taken from around the roots of crop plants on 1210 different farms and gardens, and that every sample included at least one species of nematode known to be a plant parasite, with root-knot nematodes making only 3.2 % of the total. A 1959 report from New Jersey states that, on the basis of 2500 soil and root samples taken since 1954, a very conservative estimate of annual loss in the state is $15 million. The root-knot nematodes which are reduced by cold winters, were in third place because of their importance as pests of greenhouse crops, including African-violets, roses, and other ornamentals, as well as vegetable seedlings. Nematodes (eelworms or roundworms) are threadlike animals in the phylum Nematoda (or Nemata). The following two references were used in the nematode taxonomic descriptions in this section:

Nickle WR (1991) Manual of agricultural nematology. Dekker, New York. 1035pp

Blaxter ML, DeLey P, Garey JR, Liu LX, Scheldeman P, Vierstraete A, Vanfleteren JR, Mackey LY, Dorris M, Frisse LM, Vida JT, Thomas WK (1998) A molecular evolutionary framework for the phylum Nematoda. Nature 392(6671):71–75.

Nematodes live in moist soil, water, decaying organic matter, and tissues of other living organisms. Some cause diseases of man or animals; others cause plant diseases. The animal parasites include hookworms, pinworms, and the worms in pork causing trichinosis, and they range in length from less than an inch to nearly a yard. Most plant parasites are practically microscopic in size, sometimes just barely visible to the naked eye. They mostly range from 0.5 to 2 mm long, or from 1/50 to 1/10 inch.

Nematode diseases of plants are not new. The wheat eelworm was recorded more than two centuries ago (in 1743); root knot has been a recognized problem since 1855. Our systematic investigation of plant parasitic nematodes is very new. Only in the past few years have we made surveys to find out how widespread nematodes are and how many cases of "decline" in plants are due to them. Nematodes injure plants directly by their feeding, causing cell death or gross modifications and general stunting, and indirectly by affording entrance to bacteria and fungi causing

R.K. Horst, *Westcott's Plant Disease Handbook*, DOI 10.1007/978-94-007-2141-8_38,

rots and wilts. Some nematodes also are vectors of ring spots and other virus diseases.

Many nematodes may merely live in the soil close to the plant and cause no damage, and a few are actually beneficial, feeding on such harmful pests as Japanese beetle grubs. Only an expert nematologist can determine species and decide which are responsible for a plant's ill health. In submitting samples to your experiment station for diagnosis, dig up roots and some surrounding soil, place immediately in a plastic bag to prevent drying out, and mail as soon as possible.

Plant parasitic nematodes may be sedentary or migratory. They do not move through soil to any great distance. Major dispersal is by shipment of infested nursery stock and soil; locally nematodes are spread on tools, and feet, in irrigation water, in plant parts, and sometimes as dry cysts by the wind. Plant nematodes are facultative or obligate parasites. They may be endoparasitic, living inside roots or other tissues, or ectoparasitic, living outside the plant, inserting only the head for feeding; and some forms are intermediate between the two types. Most plant nematodes are root parasites, but some live in stems, bulbs, leaves, or buds. Some cause galls or other distinctive symptoms; others produce a general yellowing, stunting, or dieback that is often ascribed to other causes.

Nematodes are usually long and cylindrical, tapering at both ends, round in cross section. In some genera the female is pear-shaped or saclike, but the male is always vermiform. Nematodes in general lack coloration, being transparent or with a whitish or yellowish tint. They are covered with a cuticle, made up of three main layers, largely protein, under which is a cellular layer called the hypodermis. The body cavity, pseudocoel, is filled with fluid. The body wall musculature, directly beneath the hypodermis, consists of longitudinal fibers only. This means that nematodes cannot contract transversely. They move through moist soil with a threshing motion, or a series of undulations.

Nematodes have a complete digestive tract with a mouth at the anterior end. This is surrounded by lips bearing the sensory organs, but there is no true head, and nematodes lack eyes and nose. Basically there are six lips, but they may be fused in pairs. The sense organs, amphids, are important diagnostic characters, one class of nematodes having amphids with conspicuous openings, the other having amphids with minute pores. Most plant parasitic nematodes belong to the latter group.

Behind the mouth there is a cavity (stoma), then the esophagus, the intestine, and the rectum. The latter terminates in a ventral terminal or subterminal anus in females, in a cloacal opening in males. The sexes are usually separate, but sometimes males are missing and females are hermaphroditic. The body region behind the anus or cloacal opening is called the tail.

Near the posterior end of many nematodes there is a pair of cuticular pouches called phasmids, believed to be sense organs like the amphids. They are used to divide nematodes into two main groups, the Secernentea, or Phasmidia, with phasmids, and the Adenophorea, without phasmids.

All of the plant parasitic nematodes feed by means of a stylet, which works something like a hypodermic needle. It is a conspicuous protrusible spear used to puncture tissue. In most families this is a stomatostylet, a hollow spear derived from the sclerotized walls of the buccal cavity or stoma. Commonly the nematode punctures plant tissue with its stylet, then injects a secretion from its salivary gland that predigests the food before it is sucked in through the stylet. In the family Dorylaimidae the spear is an enlarged tooth, odontostylet, originating in the esophagus wall. It is usually hollow, but in the genus *Trichodorus* the tooth (onchiostyle) is solid but grooved.

The structure of the esophagus varies in different groups and is an important diagnostic character. The esophagus commonly has one or two swellings, known as bulbs. Those provided with a glandular apparatus are true bulbs; those lacking such apparatus are pseudobulbs. True bulbs are the chief pumping and sucking structures. They may be median, situated at midlength, or posterior, at the end of the esophagus.

Control measures for nematodes include crop rotation and other cultural practices and soil

treatment with chemicals. Most chemicals are meant for fallow soil; a few are safe around living plants. Details of nematicides and their application are given in chapter ▶ Introduction. Greenhouse soils are often steam-sterilized, and plants are sometimes dipped in hot water, the duration of the soak and the temperature depending on the tolerance of the plant and the kind of nematode to be eradicated. Some plants are antagonistic to nematodes. Asparagus roots produce a chemical that is toxic to many species, and marigolds grown with or in advance of some flower crops reduce the numbers of *Pratylenchus*, lesion nematodes. Some soil fungi trap nematodes but do not provide a practical control. The endospore-forming bacterium *Pasteuria penetrans* is known to effectively suppress certain root-knot nematodes.

Anguina

Anguinidae. Endoparasitic nematodes feeding in above ground plant tissue and transforming seeds or leaves into galls. Males and females both elongate (wormlike), but females are obese. Cuticle finely striated; stylet short with well-developed basal knobs; tail coneshaped; single ovary.

Anguina agrostis Grass Nematode, serious on bent grass and chewings fescue in the Pacific Northwest. Second-stage larvae remain in sheaths near growing tips most of the year, entering embryonic flowers in late spring. There the larvae mature, and the females lay large quantities of eggs. The quickly hatching young larvae transform developing seed into elongated dark purple galls. When the galls fall to the ground, nematodes are released to reinfect grass in the vicinity. There is only one generation a year, and larvae cannot exist in moist soil more than a year without access to a host plant with developing inflorescence. The disease is important only on grass grown for seed; it is not a problem on clipped turf. When seed is threshed, galls can be carried 300 feet or more from the machines by air currents, and still further in heavy winds.

Control Rotate with a crop other than bentgrass or fescue or plow under and prevent inflorescence for 1 year. Soak seed for 2 h in tepid water with a wetting agent; then hold for 15 min at 126 °F.

Anguina balsamophila On balsam-root; galls on underside of leaves.

Anguina graminis Galls on leaves of fescue grasses.

Anguina tritici Wheat Nematode on wheat and rye, a field crop pest forming galls in place of grain. The disease was recognized in 1745, the first to be attributed to nematodes. The species is long-lived, viable nematodes having been found in seed stored 28 years. Brine flotation was the old method of eliminating galled seed.

Aphelenchoides

Aphelenchoididae. Bud and leaf nematodes, foliar nematodes. Ecto- and endoparasites; males and females wormlike, very slender; cuticle finely annulated; stylet with small basal knobs; tail with acute tip.

Aphelenchoides besseyi (including *A. oryzae*). Summer Dwarf Nematode of strawberry, present from Maryland to Louisiana, also reported from Oklahoma, Missouri, southern Illinois, California, and Washington. The nematodes live in the soil and are washed into buds by rains and irrigation water, affecting young leaves as they develop. Leaflets are crimped or crinkled, cupped, narrow, with a reddish cast to veins and petioles. Older leaves are darker green, more brittle than normal. This is a major disease in Florida, commonly noted from July to October. Cold weather checks its progress often masking symptoms, but plants do not recover; runner plants from infested mother plants are diseased. In spring the nematode population may be low, allowing nearly normal formation of early leaves, but in summer a single bud may harbor up to 1300 individuals, causing center leaves to be deformed and dwarfed. The same species causes a serious disease of rice in Arkansas and Louisiana.

Control Buy certified plants; rogue and burn diseased plants as soon as noticed. Treat dormant infested plants with hot water, 2 min at 127 °F.

Aphelenchoides fragariae (including *A. olesistus*). Spring Dwarf Nematode of

strawberry; Fern Nematode, a leaf nematode. A bud parasite of strawberry from Cape Cod to Maryland and found in scattered localities along the Pacific Coast. This is a cold-weather species, persisting through the winter with several thousand nematodes present in a single bud as leaves unfold in spring. The foliage is small twisted, thickened, glossy, with swollen petioles; blossom buds are killed or poor, and no fruit is set. Some plants are killed; others recover.

As the fern nematode, or begonia leaf blight nematode, this species is recorded on anemone, aquatic plants (*Cabomba* sp., *Limnophila* sp., *Peplis* sp., and *Potamogeton* sp.), begonia, bouvardia, calceolaria, chrysanthemum, clematis, coleus, crassula, dianthus, doronicum, fern, geranium, hosta, hydrangea, Lamium, lily, peony, primrose, saintpaulia, scabiosa, zinnia, and other ornamentals. Fern leaves have a patchy or blotched appearance with dark brown to black areas on the fronds. In some species these are rather narrow dark bands from midrib to border, limited by parallel side veins; in bird's-nest fern there is a profuse brown discoloration from the base halfway up the leaf.

On begonias the disease is most serious on semituberous varieties grown in greenhouses. Small brown spots with water-soaked margins, on underside of leaves, enlarge, coalesce, turn dark brown, and become visible on the upper surface. Whole leaves may turn dark; plants may be stunted. On fibrous-rooted begonias spots stay small, and leaves become shiny with a tendency to curl, lose color, and drop. Nematodes are spattered from plant to plant by syringing or careless watering; there is no disease spread when foliage is kept dry.

Dieback of Easter lilies grown in the Northwest is also attributed to this bud and leaf nematode. Leaves are first blotched with yellow, then turn brownish, drooping and curling against the stem (see Fig. 1). The nematodes live over in the bulbs and are splashed from leaves of one plant to another in the field. Lilies from diseased bulbs develop "bunchy-top" symptoms, with thick, twisted foliage and dieback.

Control Strawberry plants in nurseries should be inspected and certified in spring. Mother plants, near the end of the dormant period, can be treated with hot water, 2 min at 127 °F. Crop rotation helps.

Fig. 1 Foliar Nematode on Lily

Bulbs may be treated with hot water, for 1 h at 111 °F. Potted begonias can be submerged, pot and all, for 1 min at 120 °F, or for 3 min at 116 °F. African violets may be treated for 30 min at 110 °F, ferns for 10 to 15 min at the same temperature.

Aphelenchoides parietinus Causing root-plate and scale necrosis of bulbous iris.

Aphelenchoides ritzemabosi Chrysanthemum Foliar Nematode, common and serious on this host in home gardens and greenhouses, first reported in New Jersey in 1890. It is also recorded on dahlia, zinnia, and some other ornamentals but possibly confused with *A. fragariae*. A morphologically similar species produces a yellow bud blight of Vanda orchids. The first symptoms are dark spots on areas on underside of leaves, but by the fifth day after infestation discolored veins stand out sharply on upper leaf surface, and diseased leaves turn brown or black, starting in distinctive wedge-shaped areas between veins (see Fig. 2). Later the leaves dry, wither, and hang down along the stems. The nematodes swim from the soil up the stem in

Fig. 2 Leaf Nematode of Chrysanthemum. Wormlike male and female nematodes cause wedge-shaped browning between veins, followed by general blighting of leaf

a film of water, the disease going from lowest leaves progressively upward. Almost any variety may be attacked, but Koreans are particularly susceptible. The nematodes may not survive the winter in old dead leaves but they do survive in living leaves in old crowns.

Control Keep foliage dry; avoid overhead watering. Use a mulch to avoid splashing. Avoid crown divisions; make tip cuttings which are usually free from nematodes. Dormant plants can be treated with hot water, 5 min at 122 °F or 30 min at 112 °F.

Aphelenchoides ritzemabosi Current Nematode, a bud parasite on black currants and gooseberries in England; reported from California on gooseberries. Treat cuttings for 30 min in hot water, 110 °F.

Aphelenchoides subtenuis Bud and Leaf Nematode on narcissus, causing scale necrosis. Reported from the Southeast and Pacific Coast states.

Belonolaimus

Belonolaimidae. Sting nematodes, migratory obligate ectoparasites, usually found free in soil near growing tips; both sexes long, slender, with blunt ends; body strongly annulate; about 2 mm long, stylet long, with well-developed knobs; two ovaries.

Belonolaimus gracilis Sting Nematode on a wide variety of hosts from Virginia southward, also reported from New Jersey and from a rose greenhouse in Connecticut. This is a major pest of strawberries, celery, and sweet corn in Florida. It injures Bermuda, centipede, and St. Augustine grasses and seedlings of slash and long-leaf pines, being first recorded from pine. Other plants damaged by *Belonolaimus* species include peanut, pea, lupine, Austrian winter pea, cowpea, bean, lima bean, soybean, beets, cabbage, cauliflower, lettuce, endive, onion, potato, and sweet potato. The slender worms feed at root tips and along the sides. Soil fungi enter roots through feeding punctures. Roots develop short stubby branches with necrotic lesions; plants are stunted. On woody plants decline symptoms include chlorosis, twig dieback, premature dropping of fruit (such as grapefruit), and rapid wilting under moisture stress. The nematodes seem to be limited to light, sandy soils.

Control Rotate crops; cultivate to remove weed hosts.

Belonolaimus longicaudatus This species may be responsible for some of the injury ascribed to *B. gracilis*. It occurs in the same southeastern states and may injure roots of celery, peanut, grasses, cabbage, bean, and other vegetables. Potato and soybean are considered especially susceptible. It has also been reported on magnolia.

Bursaphelenchus

Aphelenchoididae. Ecto- and endoparasites; females (adult) have a vulval flap.

Bursaphelenchus lignicolus Causes wilt of pine and the nematode is vectored by cerambycid beetle (pine sawyer beetle).
Bursaphelenchus xylophilus Pinewood Nematode on pine.

Cacopaurus

Tylenchulidae. Cuticle finely annulate; female small but very obese; eggs large; male lacks stylet.
Cacopaurus pestis Reported from roots of Persian (English) walnut in California, causing typical decline with reduction in size and number of leaves, fewer nuts, eventually complete defoliation and death.

Criconema

Criconematidae. Ring nematodes, short, thick, sedentary ectoparasites; cuticle thick with spines or scales; usually found in woodlands, in damp areas, seldom in cultivated soil.
Criconema civellae Reported on citrus roots in a Maryland greenhouse.
Criconema decalineatum Fig Spine Nematode on figs.
Criconema spinalineatum Zoysia Spine Nematode on Zoysia.

Mesocriconema

Criconella xenoplax (see ►*Mesocriconema xenoplax*). Ring Nematode on peach cover crops including curly dock, perennial ryegrass, vetch, crimson clover, hairy vetch, and cowpea; also tall fescue, and white clover.
Mesocriconema xenoplax (formerly *Criconella xenoplax*). Ring Nematode on peach cover crops including curly dock, perennial ryegrass, vetch, crimson clover, hairy vetch, and cowpea; also tall fescue, and white clover.

Criconemoides (Genus dubium)

Criconematidae. Ring nematodes; short, thick-bodied; cuticle thick with retrose (inclining backward) annules; ectoparasites with a wide host range
Criconemoides annulatum On holly oak, Montana; beans and citrus, Louisiana.
Criconemoides citri Citrus Ring Nematode on citrus in Florida. The broadly annulated head is often buried deep in root tissue, which dies near the feeding puncture.
Criconemoides crotaloides On Douglas-fir and poplar, Utah.
Criconemoides curvatum Reported in large numbers on carnations but apparently not very injurious; also on grasses, Ohio.
Criconemoides cylindricum On peanut, in Georgia.
Criconemoides komabaensis On camellia, in Florida.
Criconemoides lobatum On pines, Florida; potato, New York; also grasses.
Criconemoides mutabile On marigold, D. C.
Criconemoides ornatum On grasses, Ohio.
Criconemoides parvum On grasses, Ohio.
Criconemoides rusticum On grasses, Ohio.
Criconemoides similis Cobb's Ring Nematode. Apparently an important factor in decline of peaches in Maryland and North Carolina, reported on pine in Florida and North Carolina.
Criconemoides teres On oak, California.
Criconemoides xenoplax On carnation, causing reduced root system, stunting, reduced flower yield; also reported on grape, peach and grasses.

Crossonema

Crossonema sp. Decline of Alaska cedar.

Ditylenchus

Anguinidae. Bulb and stem nematodes, slender, of moderate length, conelike tail, finely striated cuticle, mostly endoparasites.

Ditylenchus destructor Potato Rot Nematode. Feeding on underground stem structures of a large number of plants but important on potato, especially in Idaho and Wisconsin. Discolored spots on tubers progress to a gray or brown decay. The tissues have a granular appearance; they dry and shrink and the skin may crack. Invasions continue in storage, sometimes with complete destruction of tubers.

Ditylenchus dipsaci Stem and Bulb Nematode. An internal parasite of bulbs, stems, leaves, rarely roots, causing Eelworm Disease of Narcissus, Ring Disease of Hyacinth, Onion Bloat, Stem Disease of Phlox. The name *dipsaci* covers many strains and probably more than one species. The type was found in 1857 on Fuller's teasel. The nematodes are thought to release a pectinase during feeding, which results in a dissolution of the middle lamella and the production of large intercellular spaces. They injure, besides hyacinth and narcissus, grape-hyacinth, tulip, galtonia, garlic, shallot, and onion, and cause a stem disease of alfalfa and many flowers besides phlox.

The strains of hyacinth and narcissus are not reciprocally infective, although the hyacinth strain does infect onions. Hyacinths have yellow flecks or blotches on the leaves, which are often twisted, short, and split. In narcissus there are pustules or blisters, called spikkels, in leaves, which can be felt when the leaf is drawn through the fingers. Nematodes in such pustules probably enter leaves as they push up through the soil. Bulbs badly diseased at planting produce no foliage, or a few leaves that are premature, twisted, and bent.

When leaves are dry, nematodes are inactive; but when the foliage is moist and decayed, they revive and pass down into the soil or the neck of the bulb. They enter bulb scales, move down to the basal plate, and then enter the base of other scales. Infected scales are brown, and, since there is little lateral movement of nematodes, the cut surface of a bulb shows one or more brown rings contrasting with healthy tissue. Eggs, larvae, and adults are all present in the brown areas. Male and female adults are wormlike, up to 1.9 mm long. Infective larvae issue in large numbers in whitish tufts in a break between basal plate and scales, and work through the soil to invade adjacent plants.

They are also spread in irrigation water, on tools, and by animals. Some winter in weed hosts, some in seed of composites. In moist soil they die in a year or so, but they have been recovered from plants after 5 or 6 years. The strain on phlox attacks campanula, sweet william, evening primrose, goldenrod, schizanthus, anemone, foxglove, and orchids. The leaves are very narrow, crinkled, and waved, often brittle, with a tendency to lengthen petioles. Stems may be swollen near the top or bent sidewise; plants are stunted, often fail to bloom, may die prematurely. The nematodes enter through stomata of young shoots and work upward as the stems develop. They infest seed of phlox and other composites, and may be so disseminated.

In onions the inner bulb scales are enlarged, causing a split onion that seldom flowers and sometimes rots at the base. Seedlings are twisted, stunted, covered with yellow spots. On plants grown from sets, a slight stunting and flaccid condition of outer leaves is followed by leaf-tip necrosis and continued stunting. The larvae may live long in infested soil and may be carried in set onions.

Control Commercial growers routinely treat narcissus bulbs in hot water, 4 h at 110° to 112 °F. All infected plants, parts, and debris should be removed from fields and destroyed; a 2-to 4-year rotation may be tried. Take up and burn infested phlox or similar plants. Put new plants in a new location or in fumigated soil.

Ditylenchus (Sychnotylenchus) gallicus On elm.

Ditylenchus iridis Probably a strain of *D. dipsaci*, on bulbous iris. Mildly infected plants dry up prematurely and have poor root systems. Heavily infected plants are stunted, having few if any roots, and the bulbs decay before harvest. Treat bulbs with hot water as for narcissus, but soak only 3 h and as soon after curing as possible.

Dolichodorus

Dolichodoriadae. Awl nematodes similar to sting nematodes with long stylet with well-developed knobs; coarsely annulated cuticle; both sexes wormlike; male tail has a bursa (lateral extension); female has two ovaries; ectoparasites.

Dolichodorus heterocephalus Awl Nematode, causing decline of celery, bean, tomato, corn, pepper, and water chestnut in the Southeast, also recorded on pecan. It feeds largely on root tips and sometimes along the side of roots, causing necrotic lesions. It also feeds on germinating seeds and hypocotyls, sometimes penetrating the seedcoat to reach the embryo. Poor seedling emergence may be due to this nematode.

Dolichodorus (Neodolichlodorus) obtusus On arctostaphylus and pecan, California.

Dorylaimus

Dorylaimidae. Spear nematodes, with an odontostylet (hollow tooth), bottle-shaped esophagus; cuticle with longitudinal ridges; both sexes wormlike, tails rounded to cone-shaped; not proven plant parasites.

Dorylaimus spp. Found in soil near soybean, sweet potato, and other plants but not known as a pathogen.

Helicotylenchus

Hoplolaimidae. Spiral nematodes, ectoparasites or semiendoparasites; long strong stylet with basal knobs; cuticle annulated. The head is inserted in a root, but the body remains outside in a ventrically curved spiral with one or more turns.

Helicotylenchus dihystera On gardenia, corn, and bluegrass.

Helicotylenchus erythrinae Zimmerman's Spiral Nematode. Rather common in Florida around roots of grasses. Present in other states on blueberry, boxwood, cauliflower, cedar, clovers, corn, cranberry, turf grasses, oak, oat, pachysandra, pepper, pieris, pine, rhubarb, soybean, strawberry, wheat, and yew.

Helicotylenchus multicinctus Cobb's Spiral Nematode. Associated with roots of many plants, including azalea, cherry, cranberry, marsh grass, hibiscus, peach, pine, spruce, and yew.

Helicotylenchus nannus Steiner's Spiral Nematode, a small species common in the Southeast. Found damaging roots of apple, azalea, boxwood, asparagus fern, calathea, camellia, centipede grass, civet bean, gardenia, peperomia, philodendron, rubber-plant, royal palm, laurel oak, soybean, peanut, and tomato. There is a gradual decline, stunting, and failure to form flower buds.

Helicotylenchus pseudorobustus On corn, grape, tomato, and soybean.

Hemicriconemoides

Criconematidae. Ectoparasites; female with cuticular sheath, anchor-shaped stylet with anteriorly concave knobs; males without sheath or stylet. Commonly associated with turf and woody plants in warm climates, but pathogenicity not yet demonstrated.

Hemicriconemoides biformis Oak Sheathoid Nematode. On roots of oak, Florida.

Hemicriconemoides chitwoodi Associated with stunting of camellias.

Hemicriconemoides floridensis Pine Sheathoid Nematode. On pine.

Hemicriconemoides gaddi On camellias.

Hemicriconemoides wessoni On myrica, Florida.

Hemicycliophora

Criconematidae. Sheath nematodes; ectoparasites with sedentary habits; female retains last molt as an extra cuticle; knobs of stylet spheroid; males rare, without stylet.

Hemicycliophora arenaria Causing root galls on rough lemon, also reproducing in tomato, pepper, celery, squash, and bean. Celery has large, multibranched galls.

Hemicycliophora brevis On California-laurel.
Hemicycliophora obtusa On beet, Utah.
Hemicycliophora parvana Tarjan's Sneath Nematode, damaging celery in Florida, also recorded on corn, beans, and dracaena.
Hemicycliophora similis Grass Sneath Nematode. Also causes small galls on roots of blueberry and cranberry.

Heterodera and Globodera

Heteroderidae. Cyst nematodes, highly specific, attacking members of but few genera in a given plant family, partially endoparasitic, quite sedentary, attached to root by neck only. The female is lemon-shaped to globoid, white, yellow, or brown, 0.5 to 0.75 mm. Eggs are deposited or retained in body of mother, whose leathery wall forms a true cyst. Eggs remain alive for years in cysts, which are spread by wind or in soil around nonhost plants. Males are slender worms, up to 1.75 mm. Root-knot nematodes, formerly all classed as *Heterodera marioni*, have been reclassified as various species of *Meloidogyne*. The stylet *Heterodera* is twice as long as that in *Meloidogyne*, and the latter does not form true cysts.

Globodera rostochiensis (formerly *Heterodera rostochiensis*). Golden Nematode on white potatoes, also eggplant, tomato, and other members of the Solanaceae, but not on tobacco. It was first discovered in the United States on Long Island in 1941, and it was kept there, by a rigorous quarantine, until 1967, when it was found at a single location in upstate New York. In 1968, it was found on a potato farm in Delaware. Known as "potato sickness," the disease has been serious in the British Isles for many years. Crops do not show much damage until heavy populations have built up in the soil; then there is midday wilting, stunting, poor root development, early death, with up to 85 % reduction in potato yield. The eggs live in the soil inside cysts barely visible to the naked eye. Each may contain up to 500 eggs, and some hatch one year, some another. Cysts have remained viable 17 years. In spring, when soil temperature is around 60 °F, a chemical given off by potato or tomato roots stimulates hatching, and the larvae (which have had a first molt inside the egg) leave the cysts and migrate to host plants, entering the roots. The females become stationary, swell to pear shape, and break through the roots, remaining attached by a thin neck. The cylindrical males work out of the roots and cluster around to mate with the females. Eggs are formed, and the dead female becomes the cyst, first white, then gold, orange, finally brown. Cysts detached from roots remain in the soil or may be spread in potato bags, crates, machinery, even in trouser cuffs of farm workers. Lily-of-the-valley pips, cacti, and other plants intercepted at quarantine have had golden nematode cysts in fragments of soil around the roots.
Control A quarantine restricts movement of potatoes, nursery stock, root crops and top soil from infested land. Healthy potatoes are sold in paper bags to prevent reinfestation from second-hand burlap bags. The Peconic strain of potato is said to be resistant; Rosa, Elba, and NY 71 are also resistant.

Heterodera avenae Oat Cyst Nematode on pea.
Heterodera cacti Cactus Cyst Nematode. Obtained from various localities in Mexico, where it is probably indigenous, and likely to occur on cacti wherever grown. The cyst is lemon-shaped.
Heterodera carotae Carrot Cyst Nematode.
Heterodera cruciferae Cabbage Cyst Nematode, closely related to the sugarbeet nematode. On crucifers in California. Hosts include broccoli, Brussels sprouts, cabbage, cauliflower, kale, kohlrabi, mustard, radish, rutabaga, seakale, lobularia, sweet alyssum, wallflower, and garden cress.
Heterodera fici Fig Cyst Nematode on fig in Florida and California.
Heterodera glycines Soybean Cyst Nematode causing Yellow Dwarf Disease. An immigrant from Japan and Korea, first noted in North Carolina in 1954, thence spread to Arkansas, Florida, Illinois, Kentucky, Louisiana, Mississippi, Missouri, Tennessee, and Virginia. Plants are yellow, stunted; roots are small and dark with few or no bacterial nodules but with lemon-shaped brown

cysts clearly visible. This nematode reproduces only in roots of lespedeza, vetch, tomato and bean, besides soybean, but the cysts occur as contaminants of narcissus bulbs and gladiolus corms grown in infested soil and may be so disseminated.

Infested areas are under federal and state quarantines. Soil fumigation temporarily reduces nematode populations and increases plant growth and yield.

Heterodera gottingiana Pea Cyst Nematode on pea.

Heterodera humuli Hop Cyst Nematode on bean, pea, and cucumber.

Heterodera iri On grasses.

Heterodera mothi Cyst Nematode on nutsedge.

Heterodera punctata (*Punctodera punctata*). Grass Cyst Nematode found on wheat and small grains, also associated with bentgrasses in North Dakota, Michigan, and Minnesota, and turfgrass in New Jersey.

Heterodera rostochiensis (see ►*Globodera rostochiensis*). Golden Nematode on white potatoes, also eggplant, tomato, and other members of the Solanaceae, but not on tobacco.

Heterodera schachtii Sugar Beet Nematode, occurring in sugar-beet areas from California to Michigan, also infesting table beets and crucifers – cabbage, broccoli, rape, turnip, rutabaga, and radish. The females, numerous white specks clinging to roots, contain 100 to 600 eggs. Slender larvae puncture root cells with their strong stylets and pass through three molts inside the roots. The wormlike males then leave the roots to search for the flask-shaped females, which are attached to the roots only by their heads. Eggs are deposited in a gelatinous mass. These soon hatch to start other generations, but the females die with more eggs inside their bodies, which turn brown and become cysts. Eggs inside cysts may remain viable 5 or 6 years. Control depends on a very long crop rotation or soil fumigation.

Heterodera tabacum (*Globodera tabacum tabacum*). Tobacco Cyst Nematode. Reported from Connecticut on tobacco, tomato, and other solanaceous plants, but not potato; also reported on Jerusalem-cherry, eggplant, and pepper in Virginia. Stunting is also caused on tobacco.

Heterodera trifolii Clover Cyst Nematode. On clover and other legumes except peas. Spinach, beet, soybean, and carnation are minor hosts. Cysts are brown, lemon-shaped.

Heterodera zeae Corn Cyst Nematode. On sweet corn, field corn, and barley.

Hoplolaimus

Hoplolamidae. Lance nematodes, somewhat migratory, some species tropical or subtropical, of moderate length; strong stylet with basal knobs; often in a spiral or C-shape position.

Hoplolaimus coronatus On Nerine, grasses, carnation, oak, citrus, pine, sweet potato, and tomato.

Hoplolaimus galeatus (*H. coronatus*) Crown-Headed Lance Nematode, wide-spread. On turf grasses, zoysia, nursery crops, corn, sugarcane, citrus, tomato, sweet potato, pine seedlings, and carnation. This species may feed from the outside, burying the head only, or it may enter the root completely, destroying the cortex, which is sloughed off, and feeding on the phloem.

Hoplolaimus magnistylus Stunt on hibiscus.

Hoplolaimus uniformis On various ornamentals, reported from Rhode Island.

Hypsoperine

Heteroderidae. Similar to *Meloidogyne*, the root-knot nematode, but female body oval rather than pear-shaped.

Hypsoperine graminis Described in 1964 from roots of grass and forming inconspicuous galls, primarily on members of the Gramineae. St. Augustine grass may become chlorotic and die. Bermuda grass may decline. Also present on zoysia.

Longidorus and Paralongidorus

Longidoridae. Needle nematodes; relatively large ectoparasites with long, slender stylet; similar to *Xiphinema* but not causing galls.

Longidorus elongatus On grape, causing necrosis and excessive root-branching.
Longidorus maximus Reported associated with celery, leek, lettuce, and parsley.
Paralongidorus sylphus Thorn's Needle Nematode, fairly common in the Pacific Northwest, causing severe stunting of peppermint.

Meloidodera

Heteroderidae. A new genus, a link between *Heterodera* and *Meloidogyne*; eggs are retained in the female, but there is no distinct cyst stage; second stage larvae invade roots but no galls are formed.
Meloidodera floridensis In roots of slash pine in Florida.

Meloidoderita

Tylenchulidae sp. On grapes. Males developed in soil and have a degenerate esophagus that lacks a stylet.

Meloidogyne

Heteroderidae. Root-knot nematodes, formerly considered one species, now known to be several, distinguished by slight morphological differences such as striations, perineal pattern of the tail, type of galls formed, host preferences, and somewhat by locality. Females are white, pear-shaped to sphaeroid with elongated necks, slender stylets with well-developed basal knobs; males are slender, wormlike. Females deposit eggs in a gelatinous mass, and the body is not turned into a cyst as in *Heterodera* (see Fig. 3).

Root knot is the best known nematode disease, with over 2000 plant species susceptible to one or more forms of Meloidogyne. Root knot was first reported in England, in 1865 on cucumbers; in 1876 it was recorded in the United States on violet. Infected plants are stunted; they often wilt, turn yellow, and die. The chief diagnostic symptom is the presence of small or large swellings or galls in the roots (see Fig. 4). They are nearly round or long and irregular, but they are an integral part of the root and cannot be broken off. This differentiates them from beneficial nodules, formed on legume roots by nitrogen-fixing bacteria, which can be readily broken off.

Root-knot nematodes occur in practically every state. We used to think they were killed by northern winters, but some species can survive extreme cold. They do have fewer generations in the North and do not build up such large populations as in southern sandy or peat soils. Grasses and grains are about the only plants immune or resistant to root knot.

The long, thin young larva takes form inside the egg, breaks out, and migrates through the soil to a root. It moves in to the axial cylinder and there becomes sedentary. It injects a secretion of its esophageal glands into the tissue by means of its short buccal stylet, and this stimulates the formation of 3 to 5 giant cells around the injection point. The nematode absorbs its food from these nectarial cells the rest of its life. As it feeds, the larva swells rapidly into a sausage-shaped body, which, in the female, becomes whitish and pear-shaped, large enough to be just visible to the

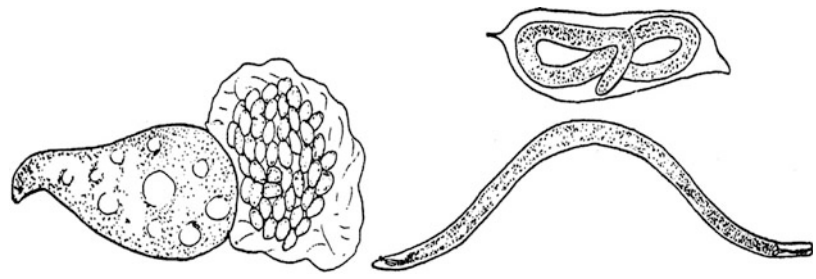

Fig. 3 Root-Knot Nematode Galls on Potato

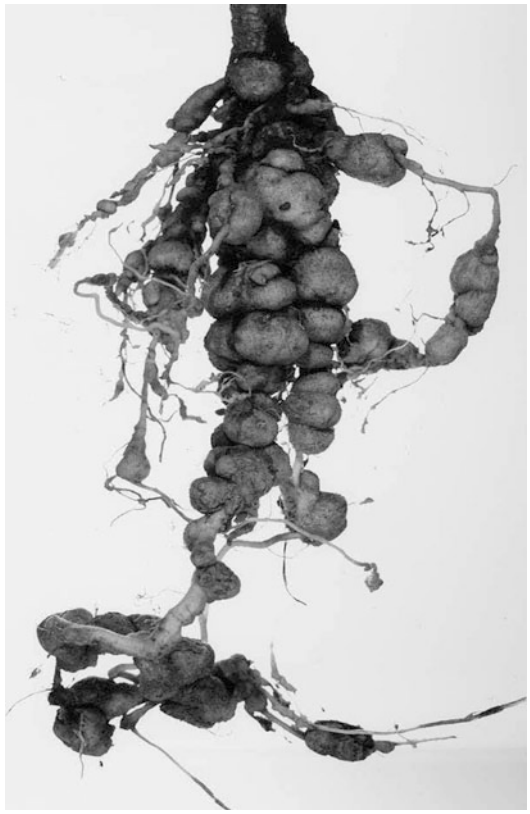

Fig. 4 Root-Knot Nematode; pear-shaped female with egg sac; encysted young larva; and wormlike adult male

naked eye. The male changes into a threadlike cylindrical form, folded up inside the larval molt, from which it finally escapes.

The female deposits its eggs in an extruded yellow-brown jelly. There may be up to 3000; the average is nearer 300 to 500. The larvae develop inside the eggs and become free in the soil when the host root cracks or decays. They may attack the same root in a new place or another root. At 80 °F a generation takes only 25 days; at 67 °F the cycle averages 87 days, and below 55 °F activity ceases. Root-knot nematodes may be injurious by their feeding punctures even if typical swellings are not formed. Some have been shown to increase Fusarium and bacterial wilts, and they almost surely complicate the crown-gall problem.

Control Rotation of crops may be practical only for species with a narrow host range, and a few varieties of vegetables, fruits, and ornamentals have been developed resistant to particular species. Soil fumigation before planting is a common control; see chapter ▶ Introduction for satisfactory chemicals. These usually kill larvae free in the soil but not all of those inside root knots.

Meloidogyne arenaria Root-Knot Nematode. Causes stunting and root gall on dwarf gardenia, compacta holly, and japanese boxwood. Also reported on watermelon.

Meloidogyne arenaria (formerly *Meloidogyne arenaria thamesi*). Thames' Root-Knot Nematode. Occurring naturally in Florida, on Chinese silk-plant (Boehmeria); found elsewhere in greenhouses. Also reported on tomato and scindapsus.

Meloidogyne arenaria thamesi (see ▶*Meloidogyne arenaria*). Thames' Root-Knot Nematode.

Meloidogyne chitwoodi Columbia Root-Knot Nematode. Has been associated with alfalfa, potato, tomato, sugar beet, wheat, and corn. This is significant because wheat and corn are commonly grown in rotation with potato and sugar beets to reduce *M. hapla*. Both monocotyledonous and dicotyledonous plant species are good hosts, indicating a wide host range for this nematode.

Meloidogyne graminicola Rice Root-Knot Nematode. On purple nutsedge and yellow nutsedge. Root-Knot Nematode on clovers.

Meloidogyne hapla Northern Root-Knot Nematode. Common on many outdoor crops in the North and in florist and nursery stock. Hosts include abelia, anoda, barberry, bean, blueberry, boxwood, California-laurel, cantaloupe, carrot, cherry, clematis, clovers, cocklebur, corn, cress, cucumber, dog fennel, eggplant, escarole, forsythia, geranium, germander, gladiolus, grape-hyacinth, goldenchain, jimsonweed, kale, lettuce, marigold, mock-orange, morning-glory, mulberry, myrtle, mustard, parsnip, pachysandra, pansy, peanut, peony, pepper, periwinkle, potato, privet, rose, sainfoin, sequoia, soybean, spirea, spurge, strawberry, sugar beet, tomato, velvetleaf, viburnum, wheat, and weigela.

This species is a particular pest of peanut and is probably the most important nematode on strawberries. It causes galls, reduces growth of

main roots, resulting in excessive branch roots; plants are stunted and may die. Injury is more serious in sandy soils. Yields have been increased by using granular Nemagon, mixed with fertilizer, as a side-dressing or by planting in fumigated beds. Rotation with corn and some grains may be practical.

Meloidogyne incognita Root-Knot Nematode. On kiwi, sequoia, society garlic, sweet potato, and jacquemontia.

Meloidogyne incognita Cotton Root-Knot Nematode. A southern native associated with many plants – forage crops, bean, cabbage, cantaloupe, carrot, celery, chard, corn, cucumber, grape, lettuce, pepper, potato, radish, rhubarb, soybean, New Zealand spinach, squash, tobacco, tomato, turnip, watermelon; also on azalea, boxwood, camellia, calthea, coleus, collinsia, daylily, gardenia, hibiscus, hollyhock, iris, India love grass, nephthytis, roystonea, schefflera, and scindapsus. It was reported on iris in 1955, from New York and Texas, the first instance of rhizomatous iris credited as host to a root-knot nematode. Tips of leaves turn yellow, then brown, with whole leaf gradually dying. There are some resistant soybean varieties, and asparagus, strawberry, and peanut can be used in a rotation.

Meloidogyne incognita Southern Root-Knot Nematode. Native to the South and common there, but overwintering as far north as New Jersey. This is the most important root-knot species on peach; it is also recorded on abelia, banana, bean, carrot, coleus, corn, cucumber, daylily, eggplant, gardenia, geranium, hibiscus, onion, okra, sweet potato, pepper, tomato, watermelon, and willow. It causes stunting and chlorosis of gardenia, but does not occur on peanuts or strawberries, and these may be used in a rotation. Resistant crotalaria and oats can be used as cover crops in peach orchards, and some peach understocks are highly resistant.

Meloidogyne javanica Javanese Root-Knot Nematode. Common in southern peach orchards and nurseries, widespread in Georgia on peaches such as Yunnan and Shali that are otherwise resistant to root knot. Found in northern greenhouses. May be associated with azalea, bean, beet, cabbage, calendula, carrot, carnation, corn, *Cocos plumosa*, cucurbits, eggplant, impatiens, radish, sequoia, snapdragon, soybean, tomato, and watermelon. Resistant peanut, strawberry, cotton, and pepper can be used in the rotation.

Meloidogyne ovalis On maple.

Naccobus

Pratylenchidae. Males wormlike; females swollen in the middle, saclike, with a short, narrow tail; eggs extruded in a gelatinous matrix or held within the body; stylet with small basal knobs; endoparasites.

Naccobus aberrans False Root-Knot Nematode. Important in western sugar-beet fields, also present on garden beets, cacti, carrot, crucifers, gaillardia, lettuce, and salsify. Root galls are similar to those caused by *Meloidogyne*, and may be fairly large.

Naccobus batatiformis On cabbage, cactus, carrot, and stock

Naccobus dorsalis Reported on heronsbill (erodium), probably on other hosts.

Nacobbodera

Heteroderidae

Nacobbodera chitwoodi Reported on Douglas fir, and spruce.

Nothanguina

Anguinidae

Nothanguina (orrina) phyllobia Foliar Nematode. On nightshade.

Paratylenchus

Tylenchulidae. Pin nematodes, related to ring nematodes but thinner, primarily ectoparasites; minute; cuticle finely annulated; female with long stylet, body ventrally curved but too short for a spiral.

Paratylenchus (*Gracilacus*) **anceps** On California-laurel.

Paratylenchus dianthus Carnation Pin Nematode. First reported on carnation in 1955 in Maryland, now well distributed through the Northeast.

Paratylenchus elachistus On Boehmeria.

Paratylenchus (*Gracilacus*) **epacris** California Sessile Nematode. Associated with a decline of black-walnut trees in California.

Paratylenchus hamatus Celery Pin Nematode, Fig Pin Nematode. On azalea, bean, boxwood, celery, chrysanthemum, clover, corn, fig, geranium, gladiolus, turf grasses, hemlock, holly, horse-radish, iris, oak, onion, parsley, peach, pieris, pine, mountain-pink, prune, rose, soybean, strawberry, and tomato. This species is responsible for celery losses in New England, plants being stunted and chlorotic, and with decline of fig in California, symptoms being chlorosis and leaf drop and undersized fruit. On mint it has caused one-third reduction in growth. The nematodes can be starved out of celery fields by a 2-year rotation with lettuce and spinach.

Paratylenchus micoletzkyi On marigold.

Paratylenchus macrophallus On mint.

Paratylenchus projectus Reported from Maryland in 1955 on pasture grasses, also found on roots of alfalfa, bean, clover, corn, spruce, and soybean. A serious decline of celery and parsley in New Jersey was attributed to this species. Preplanting fumigation has produced a striking growth response.

Paratylenchus penetrans On snapdragon.

Pratylenchus

Pratylenchidae. Lesion nematodes, sometimes called root-lesion or meadow nematodes, widely distributed migratory endoparasites; males and females wormlike, small, 0.3 to 0.9 mm, with short stylet. Conspicuous necrotic spots are formed on roots, and eggs are deposited in root tissues or in soil. Feeding punctures afford entrance to pathogenic microorganisms.

Pratylenchus brachyurus (*P. leiocephalus*) Godfrey's Meadow Nematode, Smooth-Headed Meadow Nematode. On corn, grasses, cereals, asparagus, avocado, citrus, collinsia, dogwood, peanut, pieris, pine, pineapple, potato, soybean, strawberry, and tomato. Unsightly lesions are formed on peanut shells, and the nematode survives through curing. Preplanting soil fumigation has increased yield.

Pratylenchus coffeae (*P. musicola*) Associated with strawberry black root and decline, in Arkansas.

Pratylenchus crenatus Associated with many kinds of nursery plants.

Pratylenchus fallax Lesion nematode on grass.

Pratylenchus hexincisus Described from corn roots, Maryland.

Pratylenchus minyus On pear and grape, in California. Also, on filaree.

Pratylenchus musicola On banana, fig, olive, and walnut.

Pratylenchus nannus Lesions nematode; On zinnia.

Pratylenchus negelectus Lesion nematode on potato.

Pratylenchus penetrans Cobb's Meadow Nematode. Associated with decline in alfalfa, amaranth, apple, arborvitae, azalea, bean, blackberry, blueberry, boxelder, cabbage, carrot, cedar, celeriac, celery, cherry, chrysan themum, clover, corn, cucumber, eggplant, fern, garden balsam, gayfeather, gladiolus, grass, hemlock, holly, horseradish, lettuce, lily, maple, mock-orange, onion, parsnip, peach, pear, peony, pepper, pieris, pine, mountain-pink, phlox, plum, peach, pear, potato, raspberry, rose, safflower, sequoia, soybean, spinach, spirea, strawberry, sweet potato, tobacco, tomato, turnip, zinnia, and yarrow. This species is distributed throughout the United States. Apples have necrotic black or amber spots on white rootlets; roots may be stunted and distorted; tree vigor is reduced; leaves are small. The disease has been called "little leaf" and "rosette." The nematodes invade cortex only; secondary fungi may play a part in symptoms. Control measures include root dips and soil fumigation, hot-water treatment for strawberry stock plants, and removal of all old roots on lilies before forcing. Marigolds produce a chemical toxic to nematodes and can be used in rotations.

Pratylenchus pratensis DeMan's Meadow Nematode. Important on grasses, strawberry, lily, and narcissus; reported on a great many other hosts, but there may have been some confusion with other species.

Pratylenchus safaenis On soybean, corn, cotton, millet, rice, and sorghum.

Pratylenchus scribneri Scribner's Meadow Nematode. First reported on potatoes in 1889 in Tennessee. Associated with amaryllis, hibiscus, strawberry in Florida, roses in California, and in New Jersey, clover, corn, dahlia, orchids, parsnip, peach, potato, raspberry, rose, soybean, and tomato.

Pratylenchus subpenetrans Described from pasture grasses, Maryland.

Pratylenchus thornei Thorn's Meadow Nematode. On wheat, other grains, and grasses. It has also been reported on maple and nectarine.

Pratylenchus vulnus Walnut Meadow Nematode. Described in 1951 from California as an important parasite of walnut and rose on the West Coast, also present elsewhere. It may affect avocado, boxwood, almond, fig, forsythia, gayfeather, apricot, citrus, peach, plum, raspberry, loganberry, rose, sequoia, strawberry, Japanese boxwood, spiny Greek juniper, blue rug juniper, walnut, and yew. Soil fumigation has increased growth of roses by 400 %.

Pratylenchus zeae Corn Meadow Nematode. Associated with corn, also alfalfa, bean, chrysanthemum, cucumber, grasses, pea, phlox, potato, soybean, tobacco, and tomato.

Pratylenchus spp. Lesion Nematodes. Probably as widespread as a group as root-knot nematodes and even more serious, though less readily recognized. The brown or black root condition usually comes from secondary fungi entering and rotting the roots after cells are pierced and torn by the nematodes. In boxwood and other ornamentals there is often a brush or witches' broom of new surface roots to compensate for old roots sloughed off. First symptoms are usually yellow, black, or brown lesions on fine feeder roots. Boxwood becomes sickly, stunted; foliage is dark brown to orange, sometimes drops; some branches may be killed. Tuberous begonias may be heavily infested in roots and tubers, with poor growth. Where possible, fumigate soil before planting. Help plants to recover from root injury by mulching, adequate watering, and feeding.

Radopholus

Pratylenchidae. Burrowing nematodes; endoparasites with entire life cycle inside plants, including copulation and egg deposition. Male and female wormlike, with short stylet. Female with flat lip region, two ovaries; 0.6 mm long; male with rounded lip region.

Radopholus similis Burrowing Nematode, Associated with SPREADING DECLINE OF CITRUS. The most important citrus disease in Florida. This is a subtropical species, first reported in 1893 from banana roots in the Fiji Islands. Citrus decline was known for many years before the nematode connection was made in 1953. This species is also responsible for AVOCADO DECLINE and in 1963 was reported as infesting 237 plants in many families. Possible hosts include acanthus, allamanda, aluminum plant, calathea, Barbados cherry, banana, castorbean, cocculus, hibiscus, Japanese boxwood, Japanese persimmon, ixora, jacobinia, gingerlily, loquat, *Momordica*, pandanus, peperomia, philodendron, periwinkle, pothos, podocarpus, palms, guava, as well as corn, pepper, tomato, and other vegetables, and various trees. Asparagus, marigold, and crotalaria are among the few nonhosts. The burrowing nematode has been found in Louisiana as well as central Florida.

The nematodes enter the cortical parenchyma of young succulent roots just back of the tip and form burrows, leaving behind avenues of infection for soil fungi and bacteria. Infected trees seldom die outright, but have poor growth and cease to produce a profitable crop. The disease spreads in all directions from an infected specimen, but somewhat unevenly, the distance ranging from 25 to 200 feet in a year, averaging about 50 feet. Long-distance spread is by transplants from nurseries.

Control Living trees, once infected, cannot be restored to vigor. Diseased trees in quarantined areas are pulled and burned, including two trees

beyond those known to be infested in an orchard, and the soil is treated with D-D. Bare-rooted nursery stock can be treated with hot water, 10 min at 122 °F. After the "pull and treat," nonhosts are grown for 2 years before citrus is replanted. There is some hope of resistant varieties.

Rotylenchulus

Hyplolaimidae. Reniform nematodes, partially endoparasitic root parasites. Female swollen, kidney-shaped; two ovaries; male wormlike, unable to feed.

Rotylenchulus reniformis Reniform Nematode. First described from pineapple roots in Hawaii, now found in Florida and other warm states on turf, cotton, peanut, sweet potato, tomato, gardenia, jacquemontia, and other ornamentals. The head of the female, with elongated neck, goes in the cortical parenchyma of the rootlet, and her kidney-shaped body projects outside. It is covered with a gelatinous material containing eggs and larvae, so that soil particles adhere.

Rotylenchus

Hoplolaimidae. Spiral nematodes, worldwide in temperate and tropical climates; mostly ectoparasitic but partially endoparasitic, somewhat migratory; body wormlike but held in shape of a spiral; long stylet; female with two ovaries; 0.5 to 1 mm long.

Rotylenchus blaberus Spiral Nematode on spider-lily.

Rotylenchus buxophilus Boxwood Spiral Nematode. Associated with boxwood decline in Maryland and nearby states; also found with barberry, privet, and peony. The roots have minute brown spots, and the root system is much reduced.

Rotylenchus cristiei On grasses.

Rotylenchus robustus Reported on azalea.

Rotylenchus uniformis Reported on many ornamental trees and shrubs in New Jersey nurseries.

Scutellonema

Hoplolaimidae. Spiral nematodes, similar to *Rotylenchus*.

Scutellonema blaberum (*Rotylenchus blaberus*) West African Spiral Nematode. On banana, yam, red spider lily, and African-violet.

Scutellonema brachyurum Carolina Spiral Nematode. Working at crown and roots of African-violet, destroying root cells, depositing eggs in cortical tissues. Also on amaryllis.

Scutellonema bradys Yam Nematode.

Scutellonema christiei Christie's Spiral Nematode. Common on lawn grasses in Florida, also reported on apple and grasses in Maryland and West Virginia.

Sphaeronema

Tylenchulidae

Sphaeronema sp sp. Decline of Alaska-cedar.

Tetylenchus

Belonolaimidae. Male and female wormlike, styletshort.

Merlinius joctus On blueberry.

Trichodorus and Paratrichodorus

Trichodoridae. Stubby-root nematodes; migratory ectoparasites with wide host ranges; thick-bodied, cylindrical;0.5 to 1.5 mm long; smooth cuticle; tail short, bluntly rounded; long, slender stylet is a grooved tooth.

Paratrichodorus allius Reported reducing onion yield in Oregon.

Paratrichodorus christiei Christie's Stubby Root Nematode. Wide-spread in southern states but also present elsewhere feeding on many plants in many different plant families. These include azalea, avocado, blueberry, bean, beet,

cabbage, citrus, corn, cranberry, chayote, onion, potato, squash, strawberry, tomato, and turf grasses –St. Augustine, Bermuda, and zoysia. On tomato there is general stunting and formation of short lateral roots. The stubby effect is apparently caused by a secretion and not just mechanical piercing by the stylet; there is reduced cell multiplication. The host list is too long for crop rotation to be practical, and soil fumigation is not as effective as with some other species. Asparagus and poinsettia are nonhosts, and asparagus has a nematicidal effect. This nematode and some other *Trichodorus* species are vectors of tobacco rattle virus, cause of potato corky ringspot.

Trichodorus obtusus Cobb's Stubby Root Nematode. On Bermuda grass.

Paratrichodorus pachydermus Seinhorst Stubby Root Nematode. On turf and dahlia.

Trichodorus primitivus On azalea.

Tylenchorhynchus

Belonolaidae. Stylet nematodes, sometimes called stunt nematodes, primarily ectoparasities, somewhat migratory, common in roots of nursery stock and cultivated plants. Male and female wormlike, 0.6 to 1.7 mm long; stylet variable in length with well developed knobs; female has rounded tail, two ovaries; male tail is pointed; cuticle coarsely annulated.

Tylenchorhynchus brevidus On grasses.

Tylenchorhynchus capitatus Causes stunting and chlorosis of pepper, bean, tomato, and sweetpotato.

Tylenchorhynchus claytoni Tesselate Stylet Nematode. Common and widespread through southeastern and eastern states. Associated with and romeda, apple, arborvitae, azalea, bean, blueberry, boxwood, broccoli, cherry, cereals, clovers, corn, cranberry, dogwood, forsythia, grape, grasses, hemlock, holly, lettuce, lilac, maple, peach, peanut, pepper, pine, potato, raspberry, rhododendron, soybean, strawberry, sweet potato, tomato, tulip-tree, veronica, willow, and yew. Azaleas may be severely injured, with reduced root system, short twigs, leaf chlorosis and increased susceptibility to winter injury. Soil treatment with the standard fumigants and also with systemics gives adequate control. Nonhosts include peanut, pepper, cucumber, and crotalaria.

Tylenchorhynchus dubius Reported on cereals, grasses, clovers, also azalea and carnation.

Tylenchorhynchus annulatus (formerly *Tylenchorhynchus martini*). Sugarcane Stylet Nematode. On sugarcane, rice, soybean, and sweetpotato.

Tylenchorhynchus martini (see ▶*Tylenchorhynchus annulatus*). Sugarcane Stylet Nematode. On sugarcane, rice, soybean, and sweet potato.

Tylenchorhynchus maximus On turf.

Tylenchulus

Tylenchulidae. Female sedentary, with elongated anterior portion entering the root and swollen, flask-shaped posterior outside the root; well-developed stylet with large basal knobs; male remains small, cylindrical; does not feed.

Tylenchulus semipenetrans Citrus Nematode. First noted in California in 1912, now widespread in citrus regions; important in California and Florida, present also in Arizona and Texas. Hosts other than citrus include olive, persimmon, grape, and lilac. Citrus trees exhibit a slow decline resulting from reduced root activity. Symptoms also include twig dieback, chlorosis and dying of foliage, wilting under moisture stress, and reduced fruit production. Control measures include resistant rootstock, and hot-water treatment of nursery stock, 25 min at 113 °F or 10 min at 116 °F.

Tylenchus

Tylenchidae. This genus, described in 1865, originally contained most species with stomato-stylets, but many of these have been transferred to other genera. Those left are common in soil around plants but apparently not important parasites.

Xiphinema

Longidoridae. Dagger nematodes; very common migratory ectoparasites; very long, males and females both wormlike; long, slender stylet from a bottle-shaped esophagus.

Xiphinema americanum American Dagger Nematode. A native, first described in 1913 from specimens taken around roots of corn, grasses, and citrus trees. Found all over the United States associated with many kinds of plants, including ash, azalea, bean, boxwood, clover, camellia, citrus, dogwood, elm, geranium, melon, oak, palm, pea, pecan, peach, pepper, pine, poplar, rose, soybean, strawberry, sweet potato, tomato, viburnum, vinca, and walnut. In addition to its causing decline and sometimes winterkill by its feeding on roots, this species is believed to transmit tomato ringspot, peach yellow bud mosaic, and grape yellow vein viruses and to increase the incidence of Cytospora canker on spruce. Dagger nematodes may be introduced into greenhouses with virgin soil from the woods and may destroy almost all the feeder roots of plants. There may be very high soil populations.

Xiphinema bakeri Dagger Nematode. On sequoia.

Xiphinema chambersi Chamber's Dagger Nematode. Causing a decline in strawberries, with stunting and sunken, reddish brown root lesions.

Xiphinema diversicaudatum European Dagger Nematode. A proven pathogen of rose, strawberry, peanut, fig, tomato, soybean, garden balsam, and other plants. This species is very common in commercial rose greenhouses, reducing vigor, causing chlorosis. Galls are formed on rose roots; they are similar to root-knot galls but more elongate and nearer the tip of the root, causing it to curl. Cleaning up a greenhouse infestation means disposal of all plants in a bed, careful sterilization of soil, and replanting with clean stock.

Xiphinema index California Dagger Nematode. Reported on Boston ivy, grape, fig monkshood vine, pistachio, and rose. Feeding in root tips causes a terminal swelling with angling of main roots, death of lateral roots.

Xiphinema radicicola Pacific Dagger Nematode. Reported on oak, in Florida.