NEMATODES

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Nematodes often cause significant tree health problems in peach orchards. Nematodes are microscopic roundworms that feed on the root systems of peach trees and other plants. This feeding may cause no damage in some cases or it may weaken or even kill the tree in other cases. The head region of a nematode contains a hollow, pointed, spear-like stylet. To feed, a nematode punctures an individual host cell with its stylet and pumps digestive enzymes into the cell. The cell contents are digested and drawn back into the nematode through the stylet. When the nematode finishes one cell, the stylet is withdrawn and a new cell is penetrated.

Nematodes that parasitize peaches can be categorized according to feeding habit as follows: (1) ectoparasites; (2) sedentary endoparasites; and (3) migratory endoparasites. Nematodes that spend their entire life cycle outside the host root, like ring nematodes, are ectoparasites. Those which feed at a permanent location within the root, like root-knot nematodes, are sedentary endoparasites. Migratory endoparasites, like root-lesion nematodes, enter plant tissues completely and carry out some part of their life cycle within the host root.

Nematodes spread very slowly under their own power, moving at most a few feet through the soil per year. They move best in coarse-textured soils that are wet, but not water logged. Nematodes are readily spread over great distances in soil clinging to farm equipment, in run-off water from rain or irrigation, or in contaminated plant material.

Several southeastern nematode species damage peach trees.

1. **Root-Knot Nematodes** (*Meloidogyne* spp.)

a) Northern root-knot, *M. hapla* Chitwood
b) Peanut root-knot, *M. arenaria* (Neal) Chitwood
c) Southern root-knot, *M. incognita* (Kofoid and White) Chitwood
d) Javanese root-knot, *M. javanica*(Treub) Chitwood

2. **Ring Nematode**, *Mesocriconema xenoplax* (Raski) Loof & de Grisse

3. **Root-Lesion Nematode**, *Pratylenchus vulnus* Allen and Jensen

ROOT-KNOT NEMATODES

Although northern and peanut root-knot nematodes can parasitize peach, problems with these two species in peaches are rare. Northern root-knot nematode is rather rare in Georgia. The major concentration of peanut root-knot nematode in Georgia is south of U.S. Highway 82 and west of Interstate 75 in the southwest corner of the state. This area is outside the major concentration of peaches. Problems with peanut root-knot nematode in this part of the state should only be expected where peaches are planted in sandier fields with a history of root-knot nematode problems on peanuts.

Figure 1. Stunting of 1-year-old peach trees planted into root-knot nematode-infested soil.

The parasitic nature of root-knot nematode was described on cucumber in 1855; they were discovered on peaches in 1889. The most common symptom of root-knot nematode problems in peach is stunted growth of young trees. Trees infected in the nursery or transplanted into heavily infested land are often severely stunted or killed during the first year (Figure 1). Trees stunted by root-knot nematode during establishment continue to be weak growing and below average in productivity. They never recover from this weakened condition. Root-knot stunted peach trees have never been successfully rejuvenated with nematicide treatment.

Bearing trees established without any sign of stunting may or may not show any above-ground symptoms of a root-knot nematode-infested root system. Trees showing above-ground symptoms may appear short of fertilizer or water, even when these are known to be present in adequate amounts. Infected trees frequently show premature leaf drop, especially during dry seasons (Figure 2). Conditions of low fertility or drought stress may bring on above-ground symptoms that would not be evident under more optimal growing conditions. Trees established without stunting frequently, if not usually, show no above-ground symptoms whatsoever, even from rather severe root-knot nematode infection of the feeder root system. The roots of all infected trees, whether above-ground symptoms are present or not, show the galling or knotting characteristic of root-knot nematode infection (Figure 3).

Figure 2. Stunting and defoliation of Lovell peach tree (left) in the presence of root-knot nematode. Check treatment on right.

Figure 3. Typical galls on peach roots caused by root-knot nematode.

The disease cycle of root-knot nematode is dependent upon temperature and moisture. After an egg hatches, the infective-stage juvenile moves along the root or through the soil and enters a susceptible root near the root tip. After entering the root, the juvenile migrates to areas of the root where food and water are transported. The developing female will not move again once a feeding site is established. Initial root penetration and feeding activities stimulate cell enlargement and cell division, which result in the familiar root galls or knots.

Under optimal conditions (77° to 86°F) the female begins to lay eggs 20 to 30 days after establishing a feeding site. The egg masses accumulate at the root surface and usually contain from 500 to 1,000 eggs/egg mass. The eggs hatch as soon as moisture is available at temperatures above about 50°F. Egg hatch increases and length of life cycle decreases as temperatures approach 75° to 85°F. Several generations occur during a growing season.

RING NEMATODE

The ring nematode, *Mesocriconema xenoplax (= Criconemella xenoplax = Macroposthonia xenoplax = Criconemoides xenoplax)* (Figure 4), plays a significant role in the peach tree short life disease complex (PTSL) by predisposing trees to death from cold damage, bacterial canker, or both. Trees weakened or killed in this manner often show a proliferation of root suckers around the base of the trunk (Figure 5). *M. xenoplax* is also known to predispose peach trees to Cytospora canker. Other ring nematode species, such as *M. ornata* and *M. sphaerocephala*, are commonly found in Georgia peach orchards. These two species have no known or suspected role in PTSL. There is no convincing evidence that they damage peach roots, though they may feed incidentally on them. They are present in association with grasses and other weeds. In peach orchards, the presence of these incidental ring nematodes makes species-specific identification a critical part of ring nematode assays. Assay results that do not specifically indicate the presence or absence of *M. xenoplax* or just give a total count of ring nematodes are worthless to the peach grower.

Figure 4. Ring nematode (*Mesocriconema xenoplax*) that is involved in the peach tree short life disease complex.

Figure 5. Suckering at the base of a dead peach tree that originated below the soil surface in the presence of ring nematode. Typical of trees dead from bacterial canker or cold injury.

Ring nematode problems occur most often in sandy soils and/or where peaches were previously grown, though they can occur wherever one attempts to grow peaches. Bacterial canker and Cytospora canker can occur in the absence of *M. xenoplax* if the trees are weakened by other factors. However, if ring nematode is found in high numbers in a peach orchard, especially a young orchard, producers should expect problems with one or both of these diseases. *M. xenoplax* populations tend to reach their highest levels in winter to early spring. The life cycle of *M. xenoplax* is generally completed in 25 to 34 days at 72° to 79°F. Adult females lay 8 to 15 eggs over a 2- to 3-day period. Eggs are deposited in close proximity to host roots or on the root surface. Feeding is required for juveniles to molt and for maturation of developing eggs within the adult females. Refer to the discussion of PTSL for additional information on this disease complex.

ROOT-LESION NEMATODE

Root-lesion nematodes, *Pratylenchus* spp., were recognized as parasites of trees and vines in California in 1927. *P. vulnus* was described as a distinct species in 1951. It was first found in Georgia peach orchards in 1969. As is the case with ring nematodes, assays for root-lesionnematodes must identify the specific species present to be of any value. Although *P. vulnus* is a peach pest, there are other species of root-lesion nematode, not parasitic to peach, that are found in orchard samples. These incidental root-lesion nematodes feed on grasses and weeds.

Feeding by root-lesion nematodes results in reduced root systems (Figure 6) and the presence of small dead spots or lesions (Figure 7) on the roots. Peach trees affected by root-lesion nematodes may become non-vigorous, unproductive, and/or show some dieback due to death and secondary rotting of the

Figure 6. Root damage caused by root-lesion nematode (*Pratylenchus vulnus*) on plum (right). Image by J. Pinochet.

Figure 7. .Root injury due to invasion by root-lesion nematode. Image by B. A. Jaffee.

feeder root system. Root-lesion nematode is not a common problem in Georgia peach orchards, but losses can be significant when *P. vulnus is* present. There is evidence that *P. vulnus* reaches its highest population levels from August to December. The life cycle of root-lesion nematodes is temperature-dependent and varies between 30 (86°F) and 92 days (59°F). *P. vulnus* is more common in warmer temperature regions. *P. vulnus* penetrates roots at a faster rate and does more damage to plants growing in sandy loam (coarse) as compared with finer textured soils.

CONTROL

Nematode control measures for peaches are best taken before planting. An orchard is expected to bear eight or more years, usually without further nematode treatment. Because it is critical that producers use the best control measures available for their situation, the proposed site must be thoroughly sampled before planting.

Nematode Sampling

Sampling time depends upon the crop history of the proposed site. If the site is an orchard scheduled for removal, two samples should be taken before the orchard is removed. Take the first sample in the late winter or spring (February to April). This sample is primarily for ring nematodes, which should be at their highest levels at this time. The second sample, taken in September to October, checks for root-lesion and root-knot nematodes. Both samples should include a generous amount of feeder roots. A spring sample may be all that is needed if both root-knot and root-lesion nematodes are found at this time. If they are not found in the spring sample, the fall sample double-checks for these species. In an old orchard site currently used for production of annual crops or pastures, spring and fall samples are also recommended. Take the spring sample before plowing or harrowing. Take the fall sample as crops mature, but before harvest. In cropland with no history of peaches, a fall sample is adequate. Take the sample as crops mature, but before harvest, which is the time of maximum root-knot nematode levels. Samples should be taken the year before trees are to be planted so the site can be evaluated prior to ordering trees. Last-minute sampling limits control options to fumigation or nothing at all.

In producing orchards, spring and fall nematode sampling should become a routine practice. Early detection of potential problems is critical for post-plant nematode control. These results will also be valuable in scheduling pruning and planning use of the land when thecurrent orchard is removed.

Collect nematode samples from moist, but not saturated, soil. Do not sample very dry soil nor add water to samples that seem dry. Because overheating will kill nematodes and ruin the samples, take a small cooler to the field in which to place bagged samples. Dead nematodes rot very quickly and will not be seen when counts are made. In an orchard, nematode samples should be taken in the tree row through the root zone. Orchard samples should include a handful of feeder roots. Using a soil sampling tube, collect soil from random locations (zig-zag pattern) over the field. When collecting samples, first remove the top 2 inches of soil, then insert the tube to a depth of 10 to 12 inches. Each site sampled should consist of approximately a pint of soil made from a composite sample consisting of 10 or more subsamples (soil probes or cores). The number of soil cores will depend on the size of the field in question: (1) if less than 1 acre, at least 10 cores should be taken; (2) from 1 to 5 acres, take 10 to 50 cores. One sample should not represent more than 5 acres. The cores from a given area should be thoroughly mixed in a clean bucket and put into a labeled plastic bag and sealed. Because nematodes often occur in hot spots, sampling small areas separately maximizes the chances of identifying hot spots in an orchard.

Your county extension agent can assist you in sending the samples to a diagnostic clinic or a nematology laboratory for assay. Sample early in the week to ensure same-week delivery to the lab. Based on the results of these assays, one of the following control measures may be selected to best meet your needs.

Rootstocks

Rootstocks, with very important limitations, can be useful in controlling root-knot nematode in peaches. The three rootstocks commonly available for peaches are Guardian, Lovell, and Nemaguard. Lovell rootstock has no specific resistance to any of the nematodes damaging peaches. Nemaguard rootstock has good resistance to two species of root-knot nematode, Southern *(M. incognita)* and Javanese (*M. javanica),* and can be used when these are the only damaging nematodes present. Nemaguard has no resistance to the other root-knot species or any of the other nematodes that damage peaches. Guardian, like Nemaguard, has demonstrated resistance to Southern and Javanese root-knot species (*M. incognita* and *M. javanica*), but Guardian is susceptible to peanut and northern root-knot nematode. Nemaguard rootstock should never be used if ring nematode, *M. xenoplax,*ispresent. Trees on Guardian rootstock are generally much more resistant to the PTSL syndrome than trees grown on Lovell or Nemaguard rootstock, whereas trees on Lovell survive longer than those on Nemaguard. If ring nematode is not present, Nemaguard rootstock can be used with relatively low risk on the lower coastal plain of Georgia (south of U.S. Highway 280). Between U.S. 280 and the fall line, Nemaguard rootstock may be used; however, it has some recognized risk of cold injury and PTSL. Use of Nemaguard in this area should be confined to cases where Southern and/or Javanese root-knot nematodes are present and *M. xenoplax* is absent. Nemaguard rootstock should not be used on the piedmont, as the risk of cold injury is too great. Wherever Nemaguard rootstock is used, a serious commitment to management, especially time of pruning, is necessary to minimize risks from winter injury. Never prune trees on Nemaguard rootstock until after February 1. Southern states vary in their recommendations of Nemaguard rootstock, and local advice from the nearest county agent should be sought whenever considering use of this rootstock. All three rootstocks are good hosts to the root-lesion nematode, *P. vulnus*, and should not be recommended as an alternative to pre-plant chemical control for this species.

Crop Rotation

Crop rotation is used to starve nematodes by growing crops on which they cannot feed and/or reproduce. Rotation is generally used for controlling root-knot nematodes. Rotation programs have an advantage in that the treatmentcan provide some income, depending on the value of the rotational crop. There are two disadvantages of crop rotation for nematode control in peaches: (1) the use of a crop rotation may delay planting the orchard two to four years and (2) there are some grass crops, such as coastal bermudagrass and bahiagrass, that will eliminate root-knot nematodes, but the reaction of the root-lesion nematodes that parasitize peach to these grasses is largely unknown. Bahiagrass is a poor host of ring nematode, *M. xenoplax*, but a three year pre-plant rotation did not increase peach tree survival on a PTSL site as compared with pre-plant wheat. Rotating land with wheat/fallow for three years prior to establishing a peach orchard has been shown to be as effective as pre-plant methyl bromide fumigation in suppressing ring nematode and increasing tree survival on a PTSL site.

Fumigation

Fumigation is effective against all nematodes that damage peaches. Fumigation works best in sandy or sandy loam soils and generally works poorly in heavy clays or clay loams. Clay soils have naturally small pore spaces and are difficult to dry; both factors contribute to restricted movement of fumigants. Fumigation will not work well in compacted soils of any texture. Compaction problems can usually be corrected in sandy soils by deep chiseling.

Thorough land preparation is essential to the success of any fumigation. If an old orchard is to be cleared, caremust be taken to remove all roots. Roots may harbor root-knot or root-lesion nematodes, protecting them from the fumigant. Roots will also be a constant source of trouble during application of nematicides, as they tangle in the shanks of the fumigation equipment. The land must be cultivated far enough in advance of fumigation to allow vegetation to decompose prior to treatment. Soil organic matter is not readily penetrated by fumigants. Organic matter may also bind fumigants, restricting their movement and reducing potential benefits. High organic matter may result in pockets of nematodes that survive treatment. The soil must be free of large clods, which the fumigant will channel around rather than penetrate.

Soil temperature and moisture at the time of fumigation are critical factors. For best results, soil temperatures at the 6- to 10-inch depth should be between 40° and 80°F. Soil moisture should be in the range of 6 to 150 centibars of water tension as measured by a device such as a tensiometer. Another rule of thumb would be that soil moisture for good seed germination will be about right for fumigation. In the Southeast, wet soil is a more common impediment to fumigation than dry soil.

The method of fumigation is also very important. The first decision will be whether to treat strips or broadcast the treatment over the whole field. Strip treatment can reduce costs by 1/2 to 2/3, but it leaves infested land in the field that cannot be treated later. Strip treatments have worked well for root-knot nematode control. Broadcast treatment has been more effective than strip treatment for ring nematode. Growers opting for strip fumigation must lay out the tree rows in advance. Center the fumigation over the future tree row. It is important to plant small grain or other cover crop in the drive rows to prevent nematode-infested soil from these untreated areas from eroding (washing) into the fumigated strips where trees will be planted.

For pre-plant fumigation of peaches, chisels should penetrate at least 12 inches below the final surface and be spaced 12 to 24 inches apart. After fumigation, the soil surface must be sealed with a roller, cultipacker, shallow harrow, or plastic to prevent too rapid escape of the fumigant. A harrow is the poorest choice.

Crop rotation and fumigation should *not* be considered as means to eradicate nematodes. The purpose of these treatments is to reduce nematodes to the lowest possible level and to allow trees to establish healthy root systems. By doing this, the trees can withstand subsequent nematode buildup without suffering loss of production or shortened life. The long-term success of any treatment depends upon the care exercised in performing each operation.

Sanitation

Clean nursery stock and equipment should be the first line of defense. All money and efforts will be wasted if nematode-infested trees are planted in treated soil. Growers should purchase trees only from reputable nurseries with good fumigation programs. The major nematode to watch for on nursery stock is root-knot nematode. Do not "heel-in" your trees in untreated land. This is a simple, but often overlooked, point. Farm equipment should be thoroughly cleaned before operating in a treated area. Soil left clinging to this equipment can reinfest an area that has been treated with a significant outlay of time and money.

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