From: *Plant Nutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture*
J. A. Silva and R. Uchida, eds. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, ©2000

Chapter 16

Plant-parasitic Nematodes and Their Management

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Poor plant growth can be caused by a wide range of factors. A common reaction to poor growth is to apply more fertilizer or irrigation water. This decision may seem logical—wilting plants sometimes need water, and leaf yellowing often indicates nutrient deficiency. However, if the symptoms are caused by nematode infection, adding more water or nutrients usually intensifies the problem: additional water can result in waterlogged soil, leading to death of the roots; excessive nutrients can create a salt problem and contribute to environmental pollution.

When plant growth problems occur, it is important to determine whether plant-parasitic nematodes are involved. If so, the nematodes must be managed to eliminate or minimize the damage. Infection by these microscopic roundworms is a major cause of poor crop yields in the tropics and subtropics. Crop damage from nematodes is not readily apparent in most cases, and it often remains hidden by the many other factors limiting plant growth. This chapter is intended to provide some insight about plant-parasitic nematodes, the damage they cause, and their management.

Making the diagnosis

Diagnosis of nematode problems is difficult because the symptoms vary with environmental conditions and the plant growth stage. The assessment of the cause is further complicated because the same symptoms may be due to other causes. In tropical and subtropical environments, most observations of wilting, stunting, discoloration, and general abnormal appearance should trigger the thought of nematodes as a possible cause. Because of the wide array of disorders that could be caused by nematodes, an assay of soil and plant tissue for nematodes is essential.

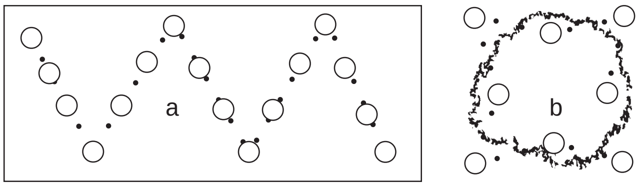
Assaying for nematodes

Soil samples are helpful in diagnosing a nematode problem or assessing other potential problems. Accurate nematode diagnosis through a soil and root assay is the key to developing a successful management program. Proper sampling is necessary to obtain a reliable and accurate estimate of the nematode population. Through the assay, the kinds and numbers of nematodes are determined—this is the necessary first step to making a management decision. Sampling the soil before planting ("preplant" sampling) is a relatively reliable procedure for predicting the potential of nematode damage. In the tropics and subtropics, however, precise or even approximate damage and economic thresholds are not established. Nevertheless, good judgments can be made with the data generated from a soil assay.

For diagnostic purposes, samples from a crop field or a group of plants can be collected any time after the plants have been growing actively for at least 2–3 weeks.

Repeated sampling increases the reliability of sampling. For preplant sampling, the repeat sampling can be done immediately. During the cropping period, the second sampling should be done a few weeks after the first.

Figure 16-1. Collect soil samples in a systematic, zigzag pattern in fields (a) or around individual trees (b).



Collecting samples for nematode assay

The proper sampling method is based on the species of nematode and its location in the soil profile, which also depends on the crop. It is important to sample in the root zone if plants are present. With turf, for example, the nematodes occur primarily in the top 4 inches (10 cm) of soil, whereas with many perennial crops such as coffee and pineapple, the highest numbers of nematodes occur at a depth of 8–20 inches (20–50 cm) in the soil.

Both large fields and small plantings such as home gardens should be sampled in a systematic, zigzag pattern. This sampling should consist of at least 15–20 uniform cores or shovel-fulls of soil composited into one sample per garden or 2–3-acre (¾ to 1¼ hectare) section of a field. A systematic pattern of sampling (Figure 16-1a) provides a high probability of obtaining an accurate sample.

Single plants (such as a tree) should be sampled beneath the leaf drip line (Figure 16-1b). The number of cores or shovels of soil taken around a tree will depend on the size of the tree canopy. For a small tree with a canopy <10 ft (3 m) in diameter, collect 6–8 cores of soil and composite them into one sample. For larger trees, sample 10–12 locations and composite them.

Sample handling immediately after collection

The composited soil should be gently mixed before withdrawing a subsample of about 1 pint (½ liter). Place the subsample into a plastic bag and seal it to prevent moisture loss. Label the sample with your name, address, name of plant (including variety), and date of sampling. This sample must be handled gently and kept out of the sun, preferably in an insulated cooler or an area that is about 70°F (21°C). Nematodes are sensitive to heat and cold extremes, and to drying. Send the sample in a cardboard box or styrofoam container to a processing laboratory, such as the CTAHR Agricultural Diagnostic Service Center.

General description of a nematode

Plant-parasitic nematodes are microscopic (usually less than 1 mm long) and are armed with a spear-like device that they use for feeding (Figure 16-2). This apparatus is inserted into the plant's cell and is used to withdraw the cell contents.

Of the hundreds of different kinds of nematodes that infect plants, only a dozen or so species are known to be economically serious root-feeding pathogens in the tropics and subtropics; however, new species are being found, so the number of species is likely to be much greater than is currently recognized. There are fewer kinds of plant-parasitic nematodes that cause significant damage by feeding on foliage, but as with the root feeding nematodes, new species are being discovered that cause significant foliar damage. If the numbers of harmful nematodes are large, plant growth is adversely affected.

The primary groups of nematodes recognized as problems in the tropics and subtropics are the root-knot, cyst, burrowing, lesion, foliar, and reniform nematodes. Although these are associated with severe crop losses, information on actual yield loss is generally lacking. Other nematodes, such as the spiral, pin, and lance nematodes, may occur in abundance but usually do not cause sufficient damage to warrant concern.

The environmental conditions in the tropics and subtropics are ideal for maximizing nematode damage. Nematodes thrive at the temperatures under which most

Figure 16-2. Schematic drawing of a female nematode

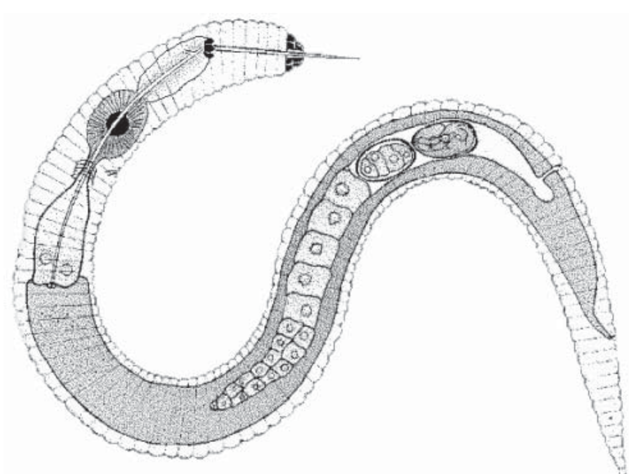


Illustration from the USDA Nematology Lab home page, <http://sun.ars-grin.gov/ars/Beltsville/barc/psi/nem/>.

Some common plant-parasitic nematodes of the tropics and subtropics

Root-knot nematode

Root-knot nematodes belong to the genus *Meloidogyne*. The two most common species in the tropics are *M. incognita* (southern root-knot) and *M. javanica* (Javanese root-knot); other species are present but occur less frequently. The root-knot nematodes feed and mature inside the roots of plants. Their feeding induces abnormal enlargements of the root, called galls. The root-knot nematode does not survive very long without a host plant, except in very low numbers and probably in the egg stage.

Diagnosis: Root galls are the primary symptom of root-knot nematodes. Species identification requires laboratory assay.

Reniform nematode

The reniform nematode, *Rotylenchulus reniformis*, has a wide host range on cultivated and noncultivated plants. The juvenile stages and males live in the soil and do not feed. The adult female is swollen and is the only parasitic stage of this nematode's life cycle. The female inserts her head and neck into the root, leaving her body outside of the root. The reniform nematode survives in the soil as eggs and coiled juveniles. This nematode causes root rotting and reduced uptake of water and soil nutrients. The symptoms are general lack of vigor, discoloration of foliage, and (or) stunted plants.

Diagnosis: The reniform nematode can be accurately diagnosed only through laboratory assay of soil and root samples.

Burrowing and lesion nematodes

Adult burrowing nematodes (*Radopholus similis*) and lesion nematodes (*Pratylenchus* spp.) cause root rot. These worm-shaped nematodes are migratory, living most of their life, including the hatching and feeding stages, inside the roots and sometimes the lower stem of their host plants. They can move through the soil from one root to another during their life cycle.

Diagnosis: The root rot caused by this nematode is not characteristic for diagnosis. It is necessary to have the soil and roots assayed to determine the numbers and kinds of nematode species present; root assays are the most reliable.

Sugar-beet cyst nematode

The sugar-beet cyst nematode (*Heterodera schachtii*), is primarily a problem on cabbage, broccoli, and cauliflower in Hawaii in the Kula, Maui, area. This nematode penetrates the root, and the female enlarges as it matures to become a white, lemon-shaped structure that breaks through the root surface at maturity. When the female dies, her body turns brown. Eggs survive inside the dead female's body (called a cyst) for many years.

Diagnosis: Direct observation of the organism with a magnifying glass is helpful, because the white cysts are about the size of the period at the end of this sentence. Root aphids are also white, so some experience may be needed to differentiate between these two white structures clinging to the roots. Confirmation by a diagnostic laboratory is recommended.

Foliar nematodes

Aphelenchoides besseyi, *A. ritzema-bosi*, and *A. fragariae* feed inside leaf tissue. The entire nematode life cycle is completed in the leaves. Plants can be stunted with deformed, discolored, or dying leaf tissue; "die-back" can also occur.

Diagnosis: Accurate identification requires laboratory assay of leaf-tissue samples.

crops and landscape plants are grown in these regions, especially where frequent rainfall or irrigation keeps the soil moist.

Rationale for making management decisions

A well informed management plan is necessary to ensure that the control practices selected can be effective, environmentally safe, and economical. Management of nematodes must focus on reducing nematode numbers to levels below the damage threshold. In annual crops, the higher the nematode population numbers at the time of planting, the lower the yield. In perennial crops, the relationship between plant growth and nematode populations is more complex. The initial numbers of nematodes are still important because they determine the early growth potential of the plant. However, even if numbers are low at planting, nematode populations will eventually increase and ultimately damage perennial plants. Thus not only must the initial populations at the time of planting be low, but also the populations must be kept at a low level if plant growth is to remain vigorous.

Manageming nematodes in tropical and subtropical environments is a challenge. There are a few control measures that are effective, and these must be used under conditions in which they will work. For effective management of nematodes, the critical steps are
(1) accurate diagnosis, and
(2) proper selection of the most effective and environmentally benign control method.

Control of nematodes

Nematode management should be multifaceted. Since eliminating nematodes is not possible, the goal is to manage their population, reducing their numbers below damaging levels. Common management methods used include planting resistant crop varieties, rotating crops, incorporating soil amendments, and applying pesticides. In some cases, soil solarization also may be practical.

Control methods not involving pesticides

Use of resistant plant cultivars is limited because there are only a few and their nematode resistance is very specific. Because resistance is specific, accurate identification of the nematode species and race is necessary before the proper cultivar can be selected. Crop resistance is ideally combined with a long-term crop rotation schedule and the best management practices available to favor vigorous and healthy plant growth.

Crop rotation involves growing a crop that is not a host for the nematode present before growing a crop that is susceptible. The nonhost or immune crop will cause nematode numbers in the soil to decline, giving the subsequent host crop a chance to establish a good root system. The success of this method depends on growing the nonhost crop long enough to reduce the nematode numbers. The rotation crop must be selected carefully because some nematodes (such as root-knot, reniform, and burrowing nematodes) have very wide host ranges. Also, some undesirable species may emerge on the rotational crop and become a pest. Variations on the crop rotation concept include fallowing, multicropping (intercropping), and green manuring.

Keeping the soil free of plants (fallow) deprives plant-parasitic nematodes of a host, which, over time, reduces their populations. Maintaining good weed control is a critical component of fallowing for nematode control because weeds are hosts of many species of plant-parasitic nematodes.

Multicropping (intercropping) with plants that either are not good nematode hosts or are antagonistic to the nematodes also reduces nematode numbers.

Green manuring—tilling under a crop that grows rapidly and produces a large quantity of biomass—adds organic matter and, depending on the green manure crop used, may add substances that repel or kill nematodes. Sudangrass and corn are excellent green manure crops that provide good nematode control.

Another nonchemical approach to controlling nematodes is biological control—using other organisms against the pest organism. A high level of natural biological control is ordinarily present in the soil. This natural control probably keeps the nematode populations at 10–20 percent of what they would be in its absence. Nevertheless, the level of natural control is seldom adequate to prevent plant damage from nematodes.

The strategy of inoculating soils with biological control organisms to increase or supplement the control organisms naturally present has proven to be unrealistic and is not recommended until more predictable inoculants are developed.

A more realistic strategy for biological control of nematodes is to incorporate soil amendments such as manure (particularly poultry manure) and compost. Such additions of organic matter contribute to biologi-

Important points about nematodes

- Nematodes are microscopic and transparent.
- Symptoms of nematode infection are often indistinct and usually mimic nutrient deficiency.
- Soil assays for the presence of nematodes are necessary for accurate diagnosis.
- Management strategies usually must be directed at the particular nematode species present.

cal activity in the soil and enhance the natural activity of organisms antagonistic to nematodes.

Solarization—heating soil under clear plastic tarps that trap and increase the sun's heat—can be an effective means of controlling nematodes in the soil. The soil needs to be moist, well tilled, and heated to at least 140 °F (60 °C) for several days, preferably several weeks. This method can be practical for home gardens, but it should be done during the hot months and long days of mid-summer.

Similarly, other heat and steam-based pasteurization methods can be used to prepare potting soil. Healthy plants grown in nematode-free media have a better chance to survive after being transplanted to the field.

Pesticides (nematicides)

Nematicides are sometimes used in agriculture, but there are few on the market. Most nematicides are highly toxic synthetic pesticides commercially available only to commercial growers. These products can be used only on particular crops, and they usually must be purchased and applied by a licensed pesticide applicator. However, several organically based nematicides are being marketed that can be purchased without a license.

Two types of nematicides are fumigants and nonfumigants. Fumigant nematicides are usually more effective, but nonfumigant nematicides can also be used effectively. Fumigant nematicides such as metam sodium and 1,3-dichloropropene are applied before planting. Some nonfumigant nematicides such as Nemacur®, Mocap®, or Vydate® are moderately effective and can be used both pre- and post-planting.

Some "natural" products claiming to provide control of nematodes have been developed from biological sources. These products have not given adequate control in research trials. Testimonials from growers indicate some response, but the apparent recovery of plants resulting from using these products can sometimes be due to growth enhancement by plant nutrients contained in the formulations. In some of these cases there is not actually a nematode problem, which results in a false indication of nematode control.

The label on the nematicide package provides application and safety information. Follow the label instructions to maximize the material's effectiveness, minimize health risk, and to be in compliance with state and federal regulations.

Suggestions for managing nematodes in the home garden

- Susceptible plants can be grown in containers with a nematode-free soil or growth media; keep the containers off the ground.
- Sow seedlings for transplanting in clean media in containers kept off the ground.
- Check the roots of container-grown nursery stock for nematode galls before transplanting them.
- Add large amounts of organic matter to the soil.
- Keep weeds controlled at all times.
- As soon as plants are not needed, pull them up or till them in to stop their roots from hosting nematodes.
- Infected plant root systems should be destroyed and not composted.
- Rotate susceptible plants with resistant or immune plants.