NEMATODES

Integrated Pest Management for Home Gardeners and Landscape Professionals

Nematodes are microscopic, eel-like roundworms. The most troublesome species in the garden are those that live and feed within plant roots most of their lives and those that live freely in the soil and feed on plant roots.

Although California has many different species of root-feeding nematodes, the most damaging ones to gardens are the root knot nematodes, *Meloidogyne* species. Root knot nematodes attack a wide range of plants, including many common vegetables, fruit trees, and ornamentals. They are difficult to control, and they can spread easily from garden to garden in soil on tools and boots or on infested plants.

A number of other nematode species also can damage home garden and landscape plants including the ring nematode (*Criconemoides xenoplax*), root lesion nematodes (*Pratylenchus* species), the sugarbeet cyst nematode (*Heterodera schachtii*), the citrus nematode (*Tylenchulus semipenetrans*) (Fig. 1), the stem and bulb nematode (*Ditylenchus dipsaci*) (Fig. 2), and others. Tables 1, 2, and 3 list some common garden plant species and their nematode pests.

LIFE CYCLE

Plant-feeding nematodes go through 6 stages—an egg stage, 4 immature stages, and an adult stage (Fig. 3). Many species can develop from egg to egg-laying adult in as little as 21 to 28 days during warm summer months. Immature stages and adult males are long, slender worms. Mature adult females of some species such as root knot nematode change to a swollen, pearlike shape, whereas females of other species such as lesion nematode remain slender worms. Nematodes are too small to be seen without a microscope.

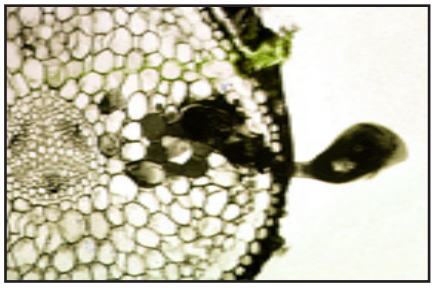

Figure 1. An adult female citrus nematodes, *Tylenchulus semipenetrans*, shown imbedded in a root cut in cross section. The nematode's front end is deep inside the root tissue while the rear end remains outside of the root.

It is believed the root knot nematode survives from season to season primarily as eggs in the soil. After the eggs hatch, the second-stage juveniles invade roots, usually at root tips, causing some of the root cells to enlarge where the nematodes feed and develop. The male nematodes eventually leave the roots, but the females remain embedded, laying their eggs into a jellylike mass that extends through the root surface and into the soil.

DAMAGE

Root knot nematodes usually cause distinctive swellings, called galls, on the roots of affected plants (Fig. 4). Infestations of these nematodes are fairly easy to recognize; dig up a few plants with symptoms (see below), wash or gently tap the soil from the roots, and examine the roots for galls. The nematodes feed and develop within the galls, which can grow as large as 1 inch in diameter on some plants but usually are much smaller.

The formation of these galls damages the water- and nutrient-conducting abilities of the roots. Galls can crack or split open, especially on the roots of vegetable plants, allowing the entry of soil-borne, disease-causing microorganisms. Root knot nematode galls are true swellings and can't be rubbed off the roots as can the beneficial, nitrogen-fixing nodules on the roots of legumes

Figure 2. Healthy onion bulb (right) and bulb infested by stem and bulb nematode.

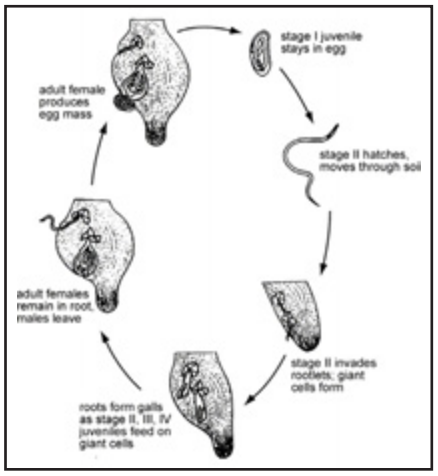

Figure 3. Life cycle of a root knot nematode.

Figure 4. Severe galling of tomato roots by root knot nematodes.

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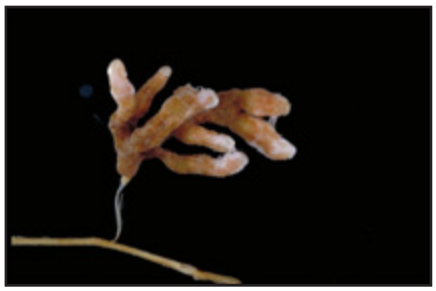

Figure 5. Nitrogen fixing nodules on roots of legumes.

Figure 6. The lettuce on the left is wilting due to root knot nematode infestation.

Figure 7. Root knot nematodes can cause galling and forking of carrot roots.

(Fig. 5). Root knot nematodes can feed on the roots of grasses and certain legumes without causing galling.

Aboveground symptoms of a root knot nematode infestation include wilting during the hottest part of the day even with adequate soil moisture, loss of vigor, yellowing leaves, and other symptoms similar to a lack of water or nutrients (Fig. 6). Infested vegetable plants grow more slowly than neighboring, healthy plants, beginning in early to midseason. Plants produce fewer and smaller leaves and fruits, and ones heavily infested early in the season can die. Damage is most serious in warm, irrigated, sandy soils.

Root injury from other nematode species can produce aboveground symptoms similar to those from root knot nematodes, but the actual injury to the roots is more difficult to detect. Roots can be shortened or deformed with no other clues as to the source of the injury (Fig. 7). You can con-

Table 1.

Landscape Plants Known or Suspected of Being Damaged by Nematodes in California.

Host plant	Nematode(s)[1]
albezia	root knot
alder	root knot
azalea	stunt
boxwood	root knot
cactus	root knot, cyst
catalpa	root knot
cedar	root knot, pinewood
euonymus	root knot
fir	dagger
ginkgo	root knot
hibiscus	root knot
hydrangea	root knot
juniper	root knot
larch	pinewood
lilac	citrus
mulberry	root knot
oak	root knot
palm	root knot
pine	pinewood
pittosporum	root knot
poinsettia	root knot
rose	root knot, root lesion
spruce	pinewood
tamarisk	root knot

[1] Most varieties susceptible to at least one species of the nematode type listed.

Table 2.

Fruits and Nuts Known or Suspected of Being Damaged by Nematodes in California.

Host plant	Nematode(s)[1]
Grapes and small fruits	
grape	root knot[2], root lesion, ring, citrus, dagger, stubby root
blackberry, raspberry	root lesion, dagger
strawberry	root knot, root lesion, foliar
Fruit and nut trees	
almond	root knot[3], root lesion, ring
apple	root knot, root lesion
apricot	root knot[4], root lesion[4], ring
avocado	root lesion
cherry	root lesion
citrus	root lesion, citrus
olive	root lesion, citrus
peach, nectarine	root knot[3], root lesion, ring
pear	root lesion
plum, prune	root lesion, ring, pin
walnut	root knot, root lesion

[1] Most varieties susceptible to at least one species of the nematode type listed.
[2] Harmony and Freedom grape rootstocks are resistant to root knot nematodes.
[3] Nemaguard and Nemared (peach) rootstocks are resistant to root knot nematodes.
[4] Royal Blenheim rootstock is resistant to root knot and root lesion nematodes.

Table 3.

Vegetables Known or Suspected of Being Damaged by Nematodes in California.

Host plant	Nematode(s)[1]
Vegetables	
beans	root knot[2], root lesion
beets	root knot, cyst
carrots	root knot
celery	root knot
cole crops	root knot, cyst
corn	root lesion
cucumbers	root knot
eggplant	root knot
garlic	stem and bulb
lettuce	root knot
melons	root knot
onions	stem and bulb
peas	root knot, root lesion, cyst
peppers	root knot
potatoes (Irish)	root knot, root lesion
potatoes (sweet)	root knot
radish	root knot, cyst
spinach	root knot, cyst
squash	root knot
tomatoes	root knot[3]
turnips	root knot, cyst

[1] Most varieties susceptible to at least one species of the nematode type listed.
[2] Some blackeye, lima, and snap bean varieties are resistant to *Meloidogyne incognita*, a species of root knot nematode.
[3] Tomato varieties designated "N" are resistant to most root knot nematode species.

firm a nematode infestation by collecting soil and root samples and sending the material to a laboratory for positive identification of the infesting species.

Although nematodes can kill annual plants, they rarely kill woody plants. Nematode injury to woody plants usually is less obvious and often more difficult to diagnose. Infested fruit and nut trees can have reduced growth and yields. Woody landscape plants that are heavily infested can have reduced growth and branch tip dieback and can defoliate earlier than normal.

Detecting Nematodes in Soil Samples

Nematodes are too small to see without a microscope. Often you become aware of a nematode problem by finding galled roots on a previous crop. However, you also can use a simple bioassay to detect root knot nematodes in garden soil. Melons seeded in pots in moist soil collected from the garden will develop visible galls on the roots in about 3 weeks when pots are kept at about 80ºF if root knot nematodes are present. As a comparison, melons planted in heat-sterilized soil won't develop galls.

MANAGEMENT

Management of nematodes is difficult. The most reliable practices are preventive, including sanitation and choice of plant varieties. You can reduce existing infestations through fallowing, crop rotation, and soil solarization. However, these methods reduce nematodes primarily in the top foot or so of the soil, so they are effective only for about a year. They are suitable primarily for annual plants or to help young woody plants establish. Once nematodes infest an area or crop, try to minimize damage by adjusting planting dates to cooler times of the season when nematodes are less active. Try to provide optimal conditions for plant growth including sufficient irrigation and soil amendments to make plants more tolerant to nematode infestation.

Sanitation

Nematodes usually are introduced into new areas with infested soil or plants. Prevent nematodes from entering your garden by using only nematode-free plants purchased from reliable nurseries. To prevent the spread of nematodes, avoid moving plants and soil from infested parts of the garden. Don't allow irrigation water from around infested plants to run off, as this also spreads nematodes. Nematodes can be present in soil attached to tools and equipment used elsewhere, so clean tools thoroughly before using them in your garden.

Resistant or Tolerant Varieties and Rootstocks

One of the best ways to manage nematodes is to use vegetable varieties and fruit tree rootstocks that are resistant to nematode injury. Tomato varieties with the code VFN (Verticillium, Fusarium, Nematodes) on the seed packet or label are resistant to common root knot nematode species. Although even resistant tomato varieties can still exhibit some root galling under high nematode levels, they usually maintain their yield. For example in recent vegetable garden-type experiments on root knot nematode soil, nematode-resistant tomatoes yielded almost 6 times more tomatoes than a similar susceptible variety. An additional benefit of growing a resistant variety is the nematode levels in the soil decline rather than increase, making it more feasible to grow a susceptible crop the following season.

For fruit trees and vines, Nemaguard rootstock used for stone fruit and almond trees and Harmony and Freedom rootstock used for grapes provide protection against root knot and other nematodes. Citrus trees growing on Troyer and Trifoliate rootstocks are resistant to the citrus nematode (Fig. 6). Consider replacing severely infested plants with plant species and varieties that are more tolerant of the nematodes present. Unfortunately, resistant varieties aren't available for many crops and ornamentals.

Fallowing and Rotation

Growing a crop on which the nematode pest can't reproduce is a good way to control some nematodes. For example, the sugarbeet cyst nematode attacks only a limited number of crops including cole crops (broccoli, Brussels sprouts, cabbage, and cauliflower) and related crops and weeds. Growing nonsusceptible crops for 3 to 5 years reduces the sugarbeet cyst nematode population to a level where you can grow susceptible crops again. Unfortunately, rotation isn't as easy for controlling root knot nematodes, because so many vegetable crops and weeds are hosts of the pest.

However, with careful planning, rotation in combination with fallowing and solarization can reduce root knot nematode numbers. Annual crops that are useful in a rotation plan for reducing root knot nematode populations include small grains such as wheat and barley, sudangrass, and resistant tomato and bean varieties.

Fallowing is the practice of leaving the soil bare for a period of time. Fallowing for 1 year will lower root knot nematode populations enough to successfully grow a susceptible annual crop. Two fallow years will lower nematode numbers even further. When fallowing, it is important to keep the soil moist to induce egg hatch and to control weeds on which nematodes can survive. As a result, eggs will hatch, but the nematodes will die if there is nothing to feed on.

You will need to repeat fallowing when you begin to see root injury again, as nematodes can build up to damaging levels even in a single season. A good way to conduct a fallowing program is to split the garden into thirds and fallow one-third every year or two on a rotating basis. If you intend to grow woody plants in a nematode-infested area, consider fallowing the soil for 4

years before planting. Table 4 gives an example of a rotation/fallowing plan that would be useful for root knot nematode control.

Table 4.

Example of a Rotation Plan for a Root Knot Nematode-infested Garden[1].

	First winter	First summer	Second winter	Second summer	Third winter	Third summer
Section A	fallow	fallow	fallow	plant summer-susceptible crop	plant winter/ spring crop	plant summer-resistant crop
Section B	plant winter/ spring crop	summer solarize	plant winter/ spring crop	plant summer-susceptible crop	fallow	summer solarize
Section C	plant winter/ spring crop	amend soil, plant summer-susceptible crop	fallow	fallow	fallow	fallow or plant summer-resistant crop

[1]Garden is divided into three sections: A, B, and C.

Soil Solarization

You can use solarization to temporarily reduce nematode populations in the top 12 inches of soil, which allows the production of shallow-rooted annual crops and helps young woody plants become established before nematode populations increase. However, solarization won't provide long-term protection for fruit trees, vines, and woody ornamental plants.

For effective solarization, moisten the soil, then cover it with a clear, plastic tarp. Leave the tarp in place for 4 to 6 weeks during the hottest part of summer. Root knot nematodes, including eggs, die when soil temperature exceeds 125°F for 30 minutes or 130°F for 5 minutes. The effectiveness of solarization is reduced in cool coastal areas, where summer temperatures commonly remain below 80°F. For a complete discussion of solarization, see *Soil Solarization* listed in References.

Planting and Harvesting Dates

Most nematode species are active during warm summer months and can't penetrate roots at soil temperatures below 64°F. Therefore, you can reduce nematode injury to fall-planted crops such as carrots, lettuce, spinach, and peas by waiting until soil temperatures have dropped below 64°F. Plant summer vegetables as early as possible in spring before nematodes become active. Plants with larger root systems, even though nematode-infested, might be able to remain productive longer. It is also helpful to remove annual vegetables, including their roots, as soon as harvest is over, to prevent nematodes from feeding and breeding on root systems.

Nematode-suppressive Plants

Certain marigolds, *Tagetes* species, suppress root knot and lesion nematodes. French marigolds (varieties include Nemagold, Petite Blanc, Queen Sophia, and Tangerine) are most effective. Avoid signet marigolds, *T. signata* or *tenuifolia*, because nematodes will feed and reproduce on these. Marigolds don't work well against the northern root knot nematode, *Meloidogyne hapla*, a species common in areas with cool winters. The effect of marigolds is greatest when you grow them as a solid planting for an entire season. When grown along with annual vegetables or beneath trees or vines (intercropping), nematode control usually isn't very good. To prevent marigold seed from getting in the soil, cut or mow the plants before the flowers open. As with other cultural control methods, nematode populations rapidly will increase as soon as you grow susceptible crops again.

Soil Amendments and Irrigation

You can add various organic amendments to the soil to reduce the effect of nematodes on crop plants. The amendments—which include peat, manure, and composts—are useful for increasing the water- and nutrient-holding capacity of the soil, especially sandy soils. Because nematodes more readily damage plants that are water-stressed, increasing the soil's capacity to hold water can lessen the effects of nematode injury. Likewise, more frequent irrigation can help reduce nematode damage. In either case, you will have just as many nematodes in the soil, but they will cause less damage.

Pesticides

Currently no chemical nematicides or soil fumigants are available to home gardeners for nematode control in backyard gardens and home landscapes.

REFERENCES

Dreistadt, S. H., J. K. Clark, and M. L. Flint. 2004. *Pests of Landscape Trees and Shrubs: An Integrated Pest Management Guide, 2nd ed*. Oakland: Univ. Calif. Agric. Nat. Res. Publ. 3359.

Elmore, C. L., J. J. Stapleton, C. E. Bell, and J. E. DeVay. 1997. *Soil Solarization: A Nonpesticidal Method for Controlling Diseases, Nematodes, and Weeds*. Oakland: Univ. Calif. Agric. Nat. Res. Publ. 21377.

Flint, M. L. 1998. *Pests of the Garden and Small Farm: A Grower's Guide to Using Less Pesticide, 2nd ed*. Oakland: Univ. Calif. Agric. Nat. Res. Publ. 3332. ❖

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