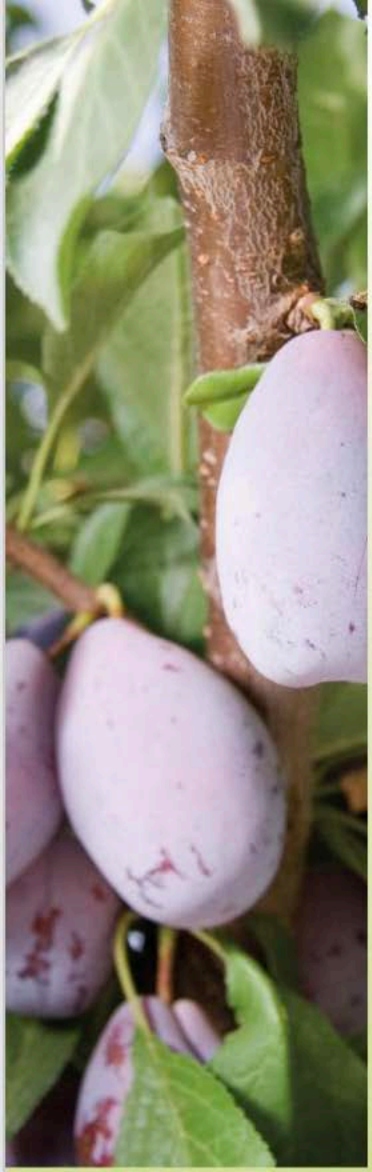

Identifying Nematodes and Diagnosing Damage......... 205
Nematodes of Greatest Concern......................... 208
Managing Nematodes in Prunes........................... 209
Nematode Protection of Current Rootstocks.......... 209
Nematode Sampling............ 210
Soil Fumigation 211
Rejection of Replants.......... 212
References......................... 212

19 Plant-Parasitic Nematodes

• Michael V. McKenry and Becky B. Westerdahl

Plant-parasitic nematodes are particularly problematic when growers purchase plants already contaminated with nematodes or when they grow a perennial crop in a field in successive seasons without rotation to a different crop. Since 1960, California has had an effective CDFA-regulated nursery certification program that halts transport of nematode-contaminated nursery stock across county lines. Today, nematode-free nursery stocks are the norm throughout the state. However, rotation of perennial crops is a grower decision that is made even more difficult because of economics and regulations associated with fumigation of soil before replanting. Selection of the best rootstock is another grower decision, and the presence or absence of certain nematode species in a field should play a role in making that decision. This chapter provides information on nematode biology, distribution, and management considerations when replanting prunes. Nematode damage is relatively subtle compared with that of other pests and diseases, but it also cannot be stopped once a field becomes infested. The most common symptoms are smaller prunes, fewer prunes, and reduced ability of the tree to take up nutrients and water from the soil.

Identifying Nematodes and Diagnosing Damage

Certain nematode species derive all their energy from the roots of plants. We call these plant-parasitic nematodes. They are microscopic: seen with a microscope that enlarges 60-fold, plant-parasitic nematodes usually have a visible spear, or stylet, at their head end (fig. 19.1). The presence or absence of a stylet provides a quick method to separate the plant-feeding types from those that feed on bacteria, fungi, algae, insects, or invertebrates, although some nematodes that feed on fungi do possess a stylet. In the surface few inches of orchard soil perhaps only 10% of the nematodes present are plant-parasitic. Deeper in the soil profile, the percentage increases to 50% or more. Plant-parasitic nematodes can migrate and reproduce anywhere the roots of a tree grow, but they tend to be most plentiful from 6 to 36 inches deep in the soil profile.

Increase the magnification of the microscope to 600-fold and it becomes apparent that there are different types of plant-parasitic nematodes (figs. 19.2, 19.3, and 19.4). The biology of these plant-parasitic nematodes can be as different as the biology of one insect type compared with another. In fact, the knowledge of which nematode is present will require diagnosis by someone trained in nematode identification. Several private laboratories in California can extract nematodes from soil or roots, identify them, and count them. The answer from the lab will indicate which plant parasites are present, how many there are, and usually whether the counts are low, medium, or high. Sampling

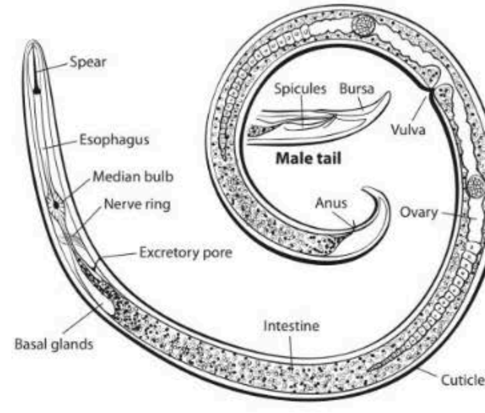

Figure 19.1 Body structure of a typical plant-parasitic nematode.

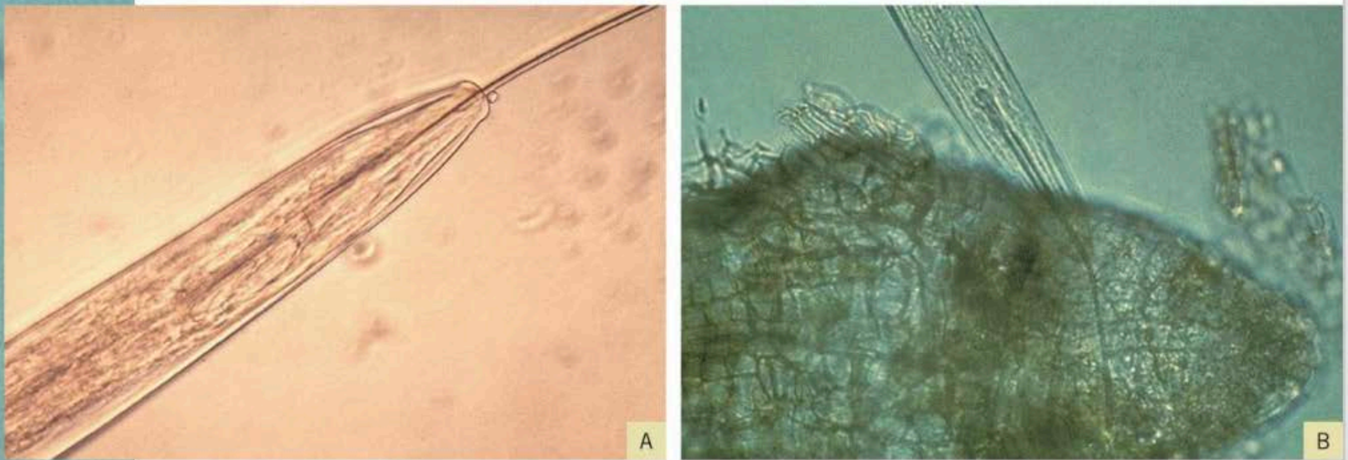

Figure 19.2 In photo (A), the spear (or stylet) of dagger nematode is extended for feeding on plant roots. In photo (B), the spear of a dagger nematode is inserted into the root for feeding. *Photos:* Department of Nematology, UC Davis.

results should also indicate the method the lab used for nematode extraction.

Prune growers in the Sacramento Valley must know whether their soil is abundant with

- ring nematode *(Mesocriconema xenoplax)*
- root lesion nematodes *(Pratylenchus vulnus, P. penetrans, P. thornei, P. neglectus,* or *P. scribneri)*
- dagger nematode *(Xiphinema americanum)*
- pin nematode *(Paratylenchus hamatus)*

Other genera and species of plant parasites may exist in the orchard, but these are the most common. Occasionally, the citrus nematode *(Tylenchulus semipenetrans)* may be found on Marianna 2624 rootstock in prune, but to this date it has not been found at a high population level. Thirty years ago, Ben Lownsberry at UC Davis reported that pin nematode could be found in 67% of prune orchards, dagger nematode in 62%, ring nematode in 38%, and root lesion nematode *(Pratylenchus vulnus)* in 7%. Prune orchards in the Sacramento Valley are usually planted on Marianna 2624 or Myrobalan 29C rootstock, and the prevailing soil is clay loam.

Prune growers in the San Joaquin and adjacent coastal valleys may find all the nematodes listed above, but several of the root lesion nematodes *(P. neglectus, P. penetrans,* and *P. thornei)* are less common, while *P. vulnus* may be found in 30% of prune orchards (McKenry 1999). Root knot nematode (*Meloidogyne* spp.) can be quite damaging on many crops grown in coarse-textured soil, but the four common prune rootstocks (except for Lovell seedling) are resistant to it. Also, some prune orchards planted in sandy soil commonly support population levels of ring nematode that are double those in the Sacramento Valley. In the San Joaquin Valley, the dominant rootstock is Nemaguard, and prevailing soils tend to be loamy sand to sandy loam. Marianna 2624 rootstock planted to loamy sand soils usually succumbs to bacterial canker complex within a few years if the site is a replant. Preplant fumigation increases the chance that trees will survive at least 3 years. Orchards may even become productive on this rootstock if a good postplant nematicide is available and applied each fall once the trees become established. Compared with Marianna 2624, Nemaguard is a slightly poorer host for ring nematode, but bacterial canker complex can kill many trees on it.

Weeds and cover crops growing on the orchard floor have relatively shallow roots that also support plant-parasitic nematodes. *Pratylenchus vulnus*, the most damaging root lesion species of concern, is not known to feed on most cover crops or weeds; it feeds instead primarily on roots of woody perennials (see fig. 19.4). By contrast, *P. thornei* and *P. neglectus* feed almost exclusively on roots of annual plants that grow on the orchard floor. *Pratylenchus penetrans,* and to a lesser extent *P. scribneri,* are known to feed on a diversity of root types, but the damage they cause to prune rootstocks has not been clarified. Several species of ring nematode, including *Mesocriconema ornata* and *M. curvatum,* feed on grasses, but *M. xenoplax* feeds on grasses and the smallest feeder roots of woody perennials (see fig. 19.3). *Paratylenchus hamatus* feeds almost exclusively on the roots of woody perennials, but several attempts have failed to show direct damage to *Prunus* rootstocks because of its feeding. *Xiphinema americanum* is an important vector of certain ring spot viruses that are not prevalent in California. This

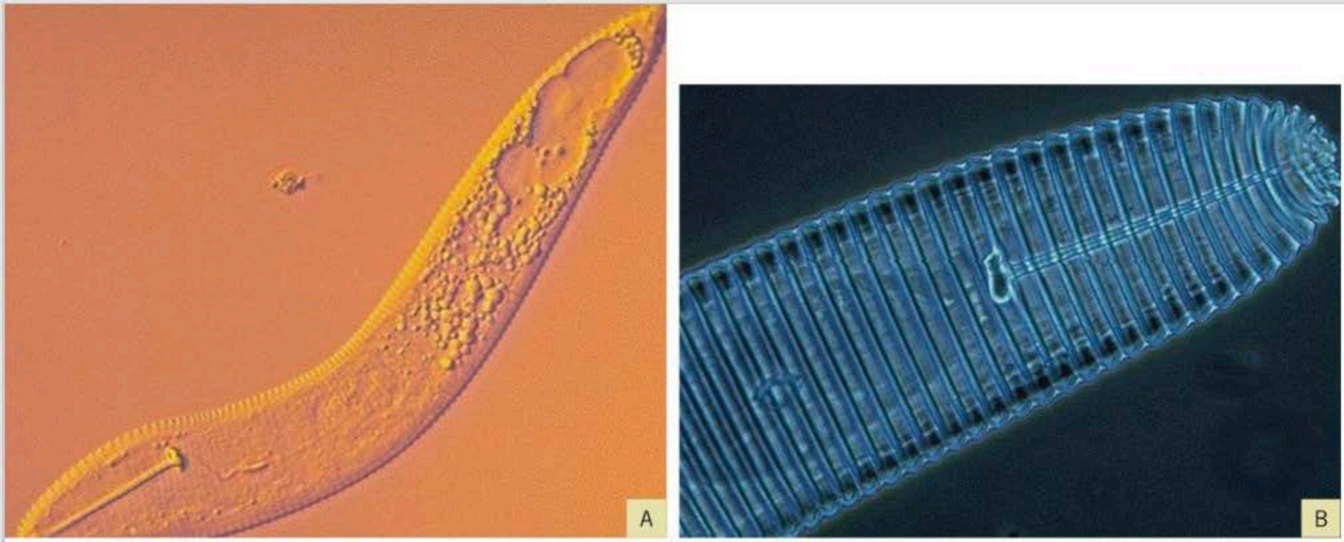

Figure 19.3 In these photos of ring nematode, the spear can be clearly seen. In photo (B), the rings around the nematode cuticle, from which the nematode gets its name, are clearly visible. *Photos:* B. Jaffee.

nematode is common in orchards, particularly where grasses and woody roots grow together, but thus far no particular damage to roots of prune trees has become apparent.

To summarize our current level of knowledge about replanting, prune growers must be concerned about *M. xenoplax* and *P. vulnus* particularly when planting after any perennial crop. It is not clear whether *P. penetrans* damages prunes, but damage does occur at high population levels. Growers must also be concerned about the rejection component of replanting, which appears as poor and uneven growth in first- and second-year plants, particularly when replanting one *Prunus* spp. after another in the San Joaquin Valley (for more information, see the section "Rejection of Replants" at the end of this chapter).

Figure 19.4 This photo of a lesion nematode in a root shows its wormlike nature and microscopic size as it is stretched out across several cells of the root. *Photo:* S. D. Van Gundy.

Nematodes of Greatest Concern

The nematodes of greatest concern in prune or plum orchards are the ring nematode *(Mesocriconema xenoplax)* and the root lesion nematode *(Pratylenchus vulnus)*. It is common for these two nematodes to occur together, but the damage they cause is quite different. The preferred feeding site of ring nematode is the smallest feeder roots. Adult stages of this nematode are sedentary, but smaller, younger stages are capable of moving through soil. It builds to its highest population levels on Marianna 2624, followed by Nemaguard, then Lovell rootstock. The ring nematode host status of Myrobalan 29C is unclear, but it is apparently a slightly poorer host than Marianna 2624. This nematode develops its highest population levels in highly porous soils. Sand, loamy sand, and coarse sandy loam soils that infiltrate water quickly provide its best habitat. Fine sandy loam soils that are relatively slow to infiltrate water will support this nematode but not at levels high enough to permit extensive population buildup. Clay loam soils that are well structured, and hence have large pore spaces, also provide adequate opportunity for ring nematode buildup. These are the same soils where Lovell or Marianna 2624 rootstocks are the preferred choice of the grower.

Several years of extensive feeding by the ring nematode can greatly reduce the abundance of young feeder roots and cause abundant populations throughout the soil profile. The nematodes are "lying in wait," and just as fruit production becomes adequate, some trees or tree limbs may suffer springtime death. The nematode predisposes the upper portion of the tree to rampant infections by *Pseudomonas syringae*. The complex disease caused by this bacterium is referred to as bacterial canker complex. In 95% of orchards with bacterial canker, the ring nematode provides the trigger for damage. There are also occasions where the nematode is not present or present at quite low population levels. In those few instances, some other field condition usually limits proliferation of small feeder roots, such as excessive soil saturation due to broken irrigation lines or leaky ditch banks. Ring nematode is also associated with dieback in the tops of trees as they age and lose vigor. Application of an appropriate postplant nematicide can noticeably invigorate such trees for as much as half a year: repeated applications are necessary to maintain the new growth.

Pratylenchus vulnus is an endoparasitic root lesion nematode that may feed and lay eggs outside or within the roots (see fig. 19.4). On occasion, the roots of prune may exhibit dark lesions due to the feeding of this nematode, but by the time this damage is evident considerable damage is under way. This nematode can oftentimes be found together with *M. xenoplax*, but *P. vulnus* by itself is not a predisposing agent of bacterial canker. Adults, juveniles, and egg stages of both of these nematodes survive in soil without food for lengthy periods of time. In settings where roots of old trees have been killed with a systemic herbicide, 5% of the original *P. vulnus* population remained in the soil for 5 years after tree removal. Survival of this nematode is greatest at 3 to 5 feet deep in the soil. Applications of Roundup to old tree trunks kill remnant roots and, coupled with 1 year of fallow, alleviate 85% of rejection. However, even with 2 years of fallow, an abundance of this nematode can remain within dead remnant roots, as well as within the soil. This root lesion nematode may feed at various locations along the young root, but it does the greatest damage if it is present at high population levels when new trees are planted. Excavation of young affected trees can often display an inadequate number of primary roots. Once trees become established, fruit size and numbers per tree will be reduced. In a 15-year evaluation in sandy loam soil, the damage level to fresh plums was 13% on Nemaguard and Lovell but 8% on Marianna 2624 and Myrobalan 29C (McKenry 1988). Although these differences were not significant, damage was visible in locations where other stress events were also present. In trials at Kearney Agricultural Center and at UC Davis, it was the presence of a sand layer located approximately 2 to 3 feet beneath the sandy loam, or clay loam soils, respectively. Water infiltration is reduced where several layers of soil exist; the result can be a limited root system aggravated further by root lesion nematode feeding.

Pratylenchus vulnus may be found in a wide range of soil textures, with population levels largely influenced by the host rather than soil type. Colt cherry rootstock, English walnut, and rose are among the best hosts, commonly supporting 1,000 nematodes per 250 cubic centimeters of soil. These are followed by black walnut (750 per 250 cc of soil); Nemaguard, Marianna 2624, and Myrobalan 29C (250 to 500 per 250 cc of soil); grape (20 to 100 per 250 cc of soil), and *Pistacia atlantica* or UCB1 rootstock

(0 to several per 250 cc of soil). This root lesion nematode is also hosted by beans and tomato but not by most weeds or rotation crops such as California alfalfa types, sudangrass, or sorghum × sudan hybrids.

Managing Nematodes in Prunes

The one best time to manage nematodes is prior to planting. Consider the following points:

- Soil fumigation has become relatively expensive, while economic returns from dried prunes have remained stagnant. A proper preplant fumigation for clay loam soils will cost double and require more care than the same fumigation applied to sandy loam soil. Methyl bromide is the preferred fumigant for clay loam soils, whereas in sand to sandy loam soils 1,3-dichloropropene applied to well-dried soil performs adequately. For more information on fumigation, see the replanting section at the UC Kearney Agricultural Center Nematode website, http://www2.uckac.edu/nematode.
- Purchase only certified nematode-free nursery stock. In California, nursery trees are required to be free of nematodes for sales that cross county lines.
- Choose the best rootstock for your soil conditions with consideration of soil texture first and the prevailing soil pests second (see chapter 6, "Rootstocks").
- Postplant nematicides such as Enzone that perform well in sandier soils may not be useful in clay loam soil. Thus, consider preplant fumigation as one of the few chemical treatments available when replanting orchards into finer-textured soil. Newer postplant nematicides are on the horizon and will appear in the UC IPM Pest Management Guidelines for Prune as they become registered and their performance quantified.
- Research is under way using what is termed a "starve and switch" tactic to replace soil fumigation. A trunk application of glyphosate herbicide followed by 1 full year of waiting can starve and alter prevailing soil ecosystems. Switching to a very different rootstock can further improve first-year tree growth, particularly if the new rootstock is known to be tolerant to rejection and also resistant or tolerant to the prevailing nematode species. The current shortfall for prune growers is the paucity of prune rootstocks with nematode resistance as well as tolerance to rejection.

Postplant nematicides can improve the vigor and yield of prunes that are infested with nematodes. There are, however, serious considerations relative to their performance.

- Nematicides that rapidly degrade within 24 to 48 hours should not be used in clay loam soils. By the time the active ingredient moves adequately through the soil and into soil particles, the concentrations are too low to provide adequate nematode reduction in clay particles. The half-life of Enzone in soil is about 24 hours. Its use in sandy soils can provide dramatic benefit, but there may be minimal benefit in most clay loam soils.
- Currently, the most economic procedure for delivering nematicides is via chemigation. The chemigation process for delivery of nematicides is not the same as it is for delivery of fertilizers. For nematicides, the goal is to reach as many roots as possible without excessively diluting the product. Research is currently under way to identify foliar-applied nematicidal agents, and some progress has been made.
- Postplant nematicides may be relatively specific in their performance. Some perform well against ring nematode but give only short-term relief against root lesion, or vice versa.

Nematode Protection of Current Rootstocks

There have been numerous examples of nematode relief due to the use of rootstocks, but decades often pass before new rootstocks actually receive evaluation against nematodes. This section reviews current rootstocks with an eye toward their nematode management value. Consult table 19.1 for a partial list of prune rootstocks and other planting choices for assistance in planning rotations that might reduce the incidence of certain nematode species.

Nemaguard is useful because of the resistance it provides to all root knot nematode (*Meloidogyne* spp.) populations throughout California. Use of this rootstock is dominant in sandier soils of the San Joaquin Valley. Its sensitivity to zinc deficiency in sandy soil can be overcome, but sensitivity to waterlogging and iron chlorosis limit its planting to the sandier soils. When evaluating a wide selection of *Prunus* species rootstocks, Nemaguard does carry some protection against the root lesion nematode (*Pratylenchus vulnus*), but it is not resistant. Against *M. xenoplax*, it is susceptible and a poor choice, but it is usually the only choice available where soil profiles are highly porous.

damage trees planted early the following spring. The key to nematode control with this material is that there must be open pore spaces in the soil for it to be effective. This can be accomplished by drying and deep ripping in preparation for the treatment.

Future use of MB is tenuous, but it has been the undeniable product of choice when fumigating finer-textured soils or soils which, even after drying, are in excess of 12% soil moisture within the surface 5 feet of the soil profile.

The alternative to MB is 1,3-D. In California, the prevailing policy is to limit applications to 33.7 gallons per treated acre. This amount can provide adequate nematode control and good relief from rejection if the soil is sandy and has received deep drying throughout the surface 5 feet of depth. At locations where soil moisture content is in excess of 12%, this amount of 1,3-D is inadequate. Clay loam soils commonly hold greater than 12% soil moisture content even after a full year of deep drying. Proper 1,3-D fumigation for soils with up to 15% soil moisture within the profile is 500 pounds per acre of 1,3-D. Soils up to 19% soil moisture content require 670 pounds per acre of 1,3-D. These latter two application rates, on a broadcast basis, are currently unacceptable in California and even if approved are quite expensive to the grower. These higher application rates can be applied as a strip application.

Rejection of Replants

In replanted orchards, poor and uneven growth from tree to tree in the first year is not generally caused by soil pests or diseases, including nematodes. With some of the trees growing poorly and others substantially better, the cause can be overirrigation, waterlogging, and Phytophthora root rot by midsummer of the first year. It is likely that the root development of these trees is being rejected by prevailing soil ecosystems. Within a year or two after replanting, the rejection component is satisfied and trees begin to grow at a rate similar to that achieved with fumigation, unless there are also known nematodes, diseases, or soil profile problems that further limit root development. A limited root system plus the presence of nematodes or diseases can result in a low-vigor orchard that may never be economical.

The intensity of rejection is not similar from tree to tree or from one region to the next. In general, experience in the Sacramento Valley tends to indicate that rejection is less damaging there than in the San Joaquin Valley. Damage by rejection can reduce first-year tree growth to one-seventh of that of fumigated trees. In the second year, the differences may lessen to one-third, but root inactivity comes when trees should have developed far-reaching root systems (for more information, see the UC Kearney Agricultural Center Nematode website, http://www2.uckac.edu/nematode). If growers replanting in the area have observed dramatic first-year growth benefits due to soil fumigation, consider rejection to be the cause rather than nematodes. Rejection may be corrected with strip fumigations at appropriate application rates or with Roundup applications to cut trunks (plus waiting 1 year). Do not expect strip applications of fumigant to protect against nematodes for more than 1 year. If the new trees are on a rootstock with resistance or adequate tolerance to the prevailing nematodes, both rejection and nematodes can be solved with a strip application of fumigant.

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