Parasitic Nematodes in Alfalfa

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Chapter 11

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Plant-parasitic nematodes are microscopic, unsegmented roundworms that frequently inhabit alfalfa fields. They can cause considerable economic losses and are often unrecognized by growers as a chronic and sometimes severe yield-reducing factor.

The nematodes that parasitize and damage alfalfa are less than one-tenth of an inch long and are found in soil, within roots, or within the crowns, stems, and leaves of plants. In the soil, nematodes live and move within the film of water that lines soil pore spaces. They are small enough to move between individual soil particles (Fig. 11.1). It is not uncommon for a single teaspoon of soil from an alfalfa field to contain 50 nematodes, or for a single inch of alfalfa stem or feeder root to contain 200.

Description

Nematodes have a relatively simple body structure (Fig. 11.2). The external covering or cuticle is transparent, permitting the major internal organs and systems, such as the digestive tract and reproductive system, to be visible when viewed through a microscope. Nematodes possess a spear or stylet that is used to pierce and feed on plant tissues (Fig. 11.3). The nematode life cycle consists of an egg stage, four gradually enlarging juvenile stages, and an adult stage (Fig. 11.4). Between each juvenile stage, nematodes

FIGURE 11.1

Soil-dwelling plant-parasitic nematodes feed on plant roots and can move within the film of water that lines soil pores.

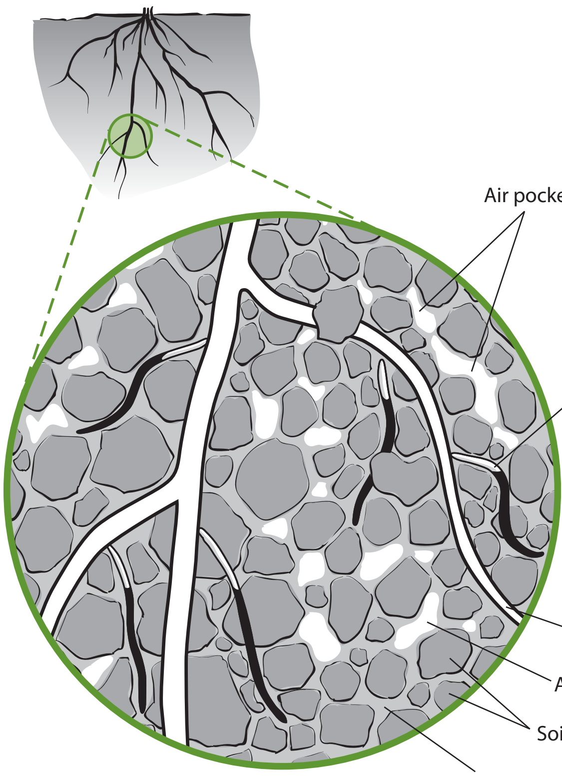


FIGURE 11.2

Body structure of a typical plant-parasitic nematode.

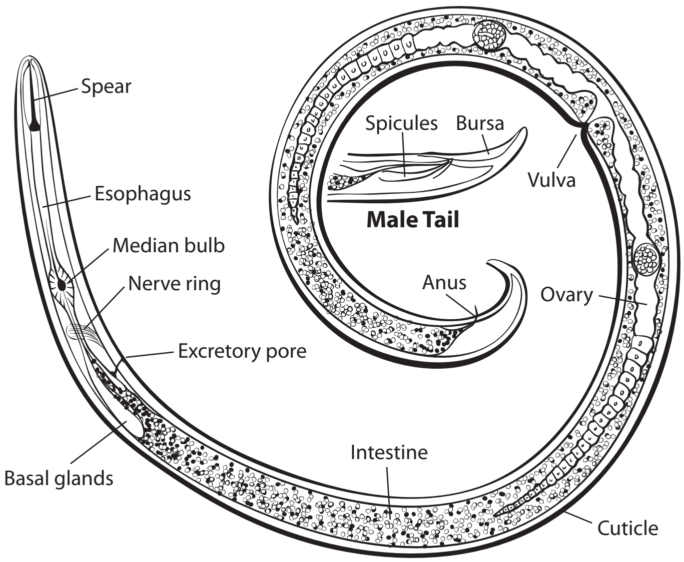


FIGURE 11.3

Nematodes use a spear (also called a stylet) to feed on plant tissue.

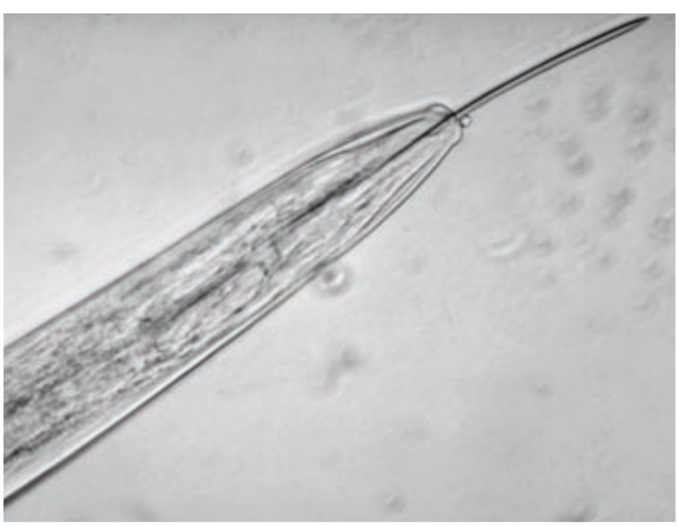
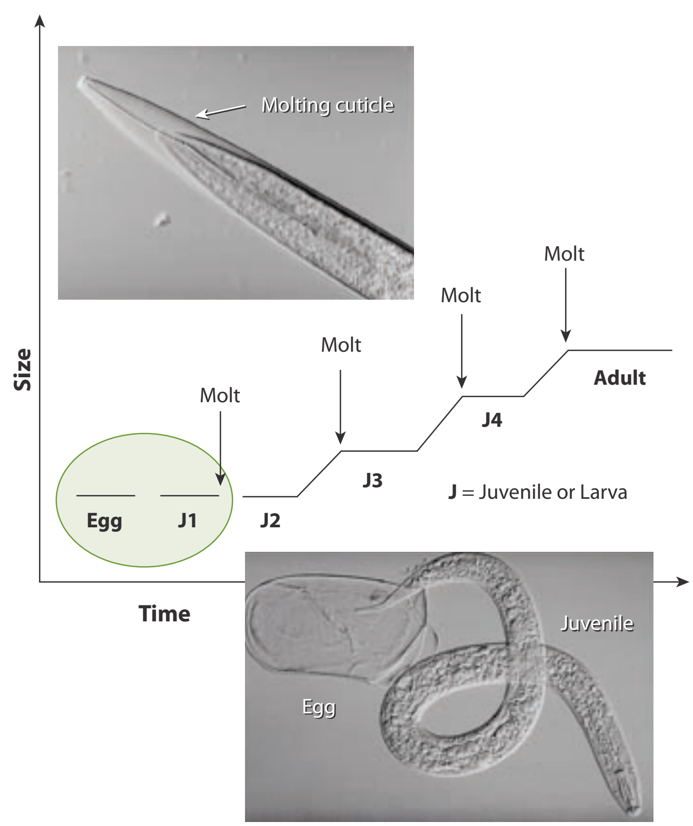


FIGURE 11.4

Life cycle of a typical plant-parasitic nematode.



molt or shed their cuticle. The length of a single generation can vary from a few days to a full year, depending on the species, the soil temperature, and other factors. Nematodes feeding on alfalfa can pass through several generations each year. Adult female nematodes can lay several hundred to one thousand eggs.

To conduct a nematode pest-management program, it is important to understand nematode biology, symptoms and signs of nematode damage, how nematodes injure plants, how to sample for nematodes, and the principles underlying various management techniques. Strategies for managing nematodes in alfalfa include site selection, the use of certified seed, using clean equipment and irrigation water, weed management, and the use of resistant varieties, crop rotation, fallow, organic amendments, and chemical nematicides.

Types of Nematodes

As many as 15 different plant-parasitic nematodes have been found in alfalfa fields in California (Table 11.1). Each species has a scientific and a common name and both are regularly used by nematologists. The common name is derived from a morphological characteristic of the nematode, from plant damage symptoms, or from the typical location of the nematode within a host.

Life-history Patterns

Nematodes commonly found in alfalfa fields exhibit several different life-history patterns (Fig. 11.5). Stubby-root, dagger, needle, ring, spiral, and stunt nematodes reside primarily outside the root and are considered ectoparasites. They use stylets to feed on roots; however, all stages of their life cycle are passed outside of roots in the soil. Stem nematodes and lesion nematodes reside primarily within the plant and are considered migratory endoparasites (living primarily inside the root). Life-cycle stages for these nematodes take place within the plant (stems, leaves, and crown for stem nematodes; roots for lesion nematodes) as well as in adjacent soil. Root-knot nematodes are sedentary (immobile) endoparasites. The second stage juvenile enters a root, takes up a permanent feeding site and then develops into an immobile adult female within the root.

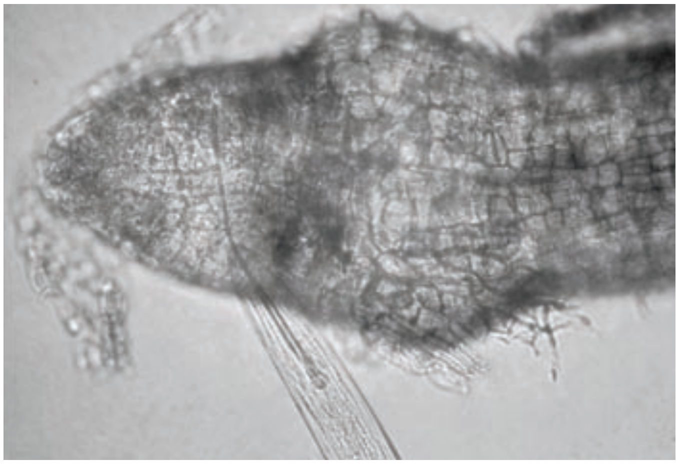
TABLE 11.1

Nematodes found in California alfalfa fields

Common Name	Scientific Name
Nematodes Commonly Causing Injury	
Stem nematode*	*Ditylenchus dipsaci* (Kuhn and Filipjev)
Northern root-knot nematode*	*Meloidogyne hapla* Chitwood
Javanese root-knot nematode	*M. javanica* (Treub, Chitwood)
Southern root-knot nematode*	*M. incognita* (Kofoid and White) Chitwood
Peanut root-knot nematode	*M. arenaria* (Neal) Chitwood
Columbia root-knot nematode	*M. chitwoodi* Golden, O'Bannon, Santo, Finley
Other Nematodes Found	
Lesion nematode*	*Pratylenchus penetrans* (Cobb) Filipjev and Schuurmans-Stekhoven
Dagger nematode	*Xiphinema americanum* Cobb
Needle nematode	*Longidorus africanus* (Micol.) Meyl
Ring nematode*	*Mesocriconema curvatus* (Raski) Loof and DeGrisse
Stunt nematode*	*Merlinius brevidens* (Allen) Siddiqi
Stunt nematode	*Tylenchorhynchus* sp. Cobb
Spiral nematode	*Helicotylenchus* sp. Steiner
Stubby-root nematode*	*Trichodorus* sp. Cobb
Stubby-root nematode	*Paratrichodorus* sp. Siddiqi

*These nematodes have been shown to reduce yields in alfalfa.

Ectoparasite (e.g., dagger nematode)



Migratory Endoparasite (e.g., stem nematode)

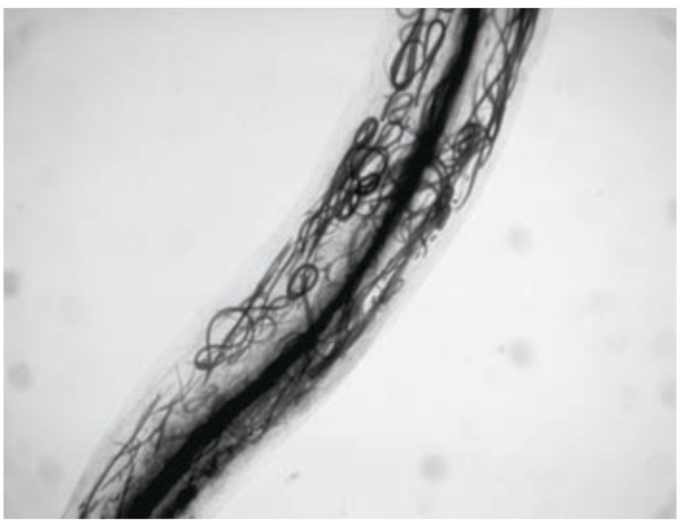
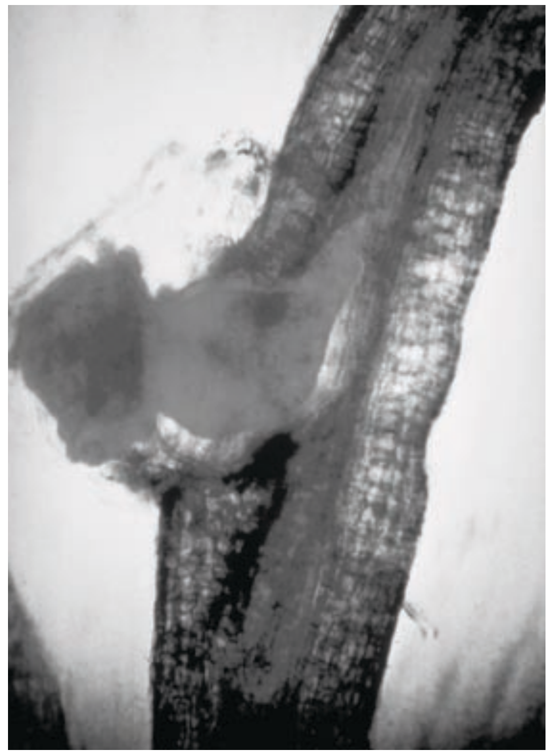


FIGURE 11.5

Examples of nematode life-history patterns. All stages of ectoparasites are found outside the root in the soil. Migratory endoparasites can be either in the root or in the soil. The juveniles of sedentary endoparasites are motile stages moving through the soil to find host roots. Once they enter a root and start to feed and become adults, they enlarge and can no longer move.

Sedentary Endoparasite (e.g., root-knot nematode)



The root cells around her head enlarge to form a gall or knot.

Knowledge of these life-history patterns can be helpful when making management decisions. For example, some nematicides, parasites, or soil amendments can be expected to be active only in the soil and so would be more effective against ectoparasites than against endoparasites. Other nematicidal agents might move systemically through the plant and would be effective against endoparasites. Beneficial parasites might be able to penetrate roots and actively seek out nematodes and would then be effective against endoparasitic nematodes.

Injury to Plant

Nematodes do not typically kill plants. They are plant stressors and act in conjunction with other stress factors in the field to reduce growth and yield. Penetration and movement by nematodes through plant tissues result in mechanical injury to cells and subsequent cell death and necrosis. Mechanical injury interrupts the uptake and flow of water and nutrients from roots and the flow of food from leaves to roots. In addition, nematodes create openings in roots through which other microorganisms can enter. For example, southern root-knot nematode (*Meloidogyne incognita* [Kofoid and White] Chitwood) can increase the severity of Fusarium wilt in alfalfa. Northern root-knot nematode (*M. hapla* Chitwood) can increase the incidence of bacterial wilt in both resistant and susceptible alfalfa cultivars. All of the above factors increase the susceptibility of plants to environmental stresses, such as moisture, freezing, or heat stress.

Because of the complex interactions that occur in the field, it is difficult to say that observed problems are specifically caused by nematodes. A number of experiments have been conducted with various nematodes on alfalfa in either greenhouse plots or microplots where conditions can be easily controlled. In these tests, the following nematodes have been shown to cause significant growth reductions: stem nematode (*Ditylenchus dipsaci* [Kuhn] Filipjev 1936); northern root-knot nematode; southern root-knot nematode; stubby-root nematode (*Trichodorus* sp. Cobb); stunt nematode (*Tylenchorhynchus clarus* Allen); lesion nematode (*Pratylenchus penetrans* [Cobb] Filipjev and Schuurmans-Stekhoven); and ring nematode (*Mesocriconema curvatus* [Raski] Loof and DeGrisse).

Only a few of the nematode species identified above are consistently associated with damage to alfalfa in the Mediterranean and desert production zones of California. The most important of those that will be covered in this chapter are stem nematode and root-knot nematode. However, if any of the nematodes mentioned above are present in a field at the time of planting, they could cause stunting of seedling alfalfa.

Root-knot Nematodes

Roots infested with root-knot nematodes may exhibit knots or galls and may branch excessively. Compared to galls formed on many other plants, root-knot galls on alfalfa are typically much smaller. Root-knot galls can be distinguished from nitrogen-fixing bacteria nodules by rubbing the roots between your fingers. Galls, unlike nodules, are not easily dislodged. Also, nodules reveal a pink coloration when rubbed between the fingers (Fig. 11.6). This pink is not apparent in galls. Symptoms above ground level include stunting, slower growth than expected, or unexplained dieback and chlorosis.

Five species of root-knot nematodes are associated with alfalfa in California. These species have wide and variable host ranges, different temperature optimums, and different degrees of pathogenicity. For example, in the San Joaquin Valley, damage from northern root-knot nematode has been more significant than damage from other species. Because of their

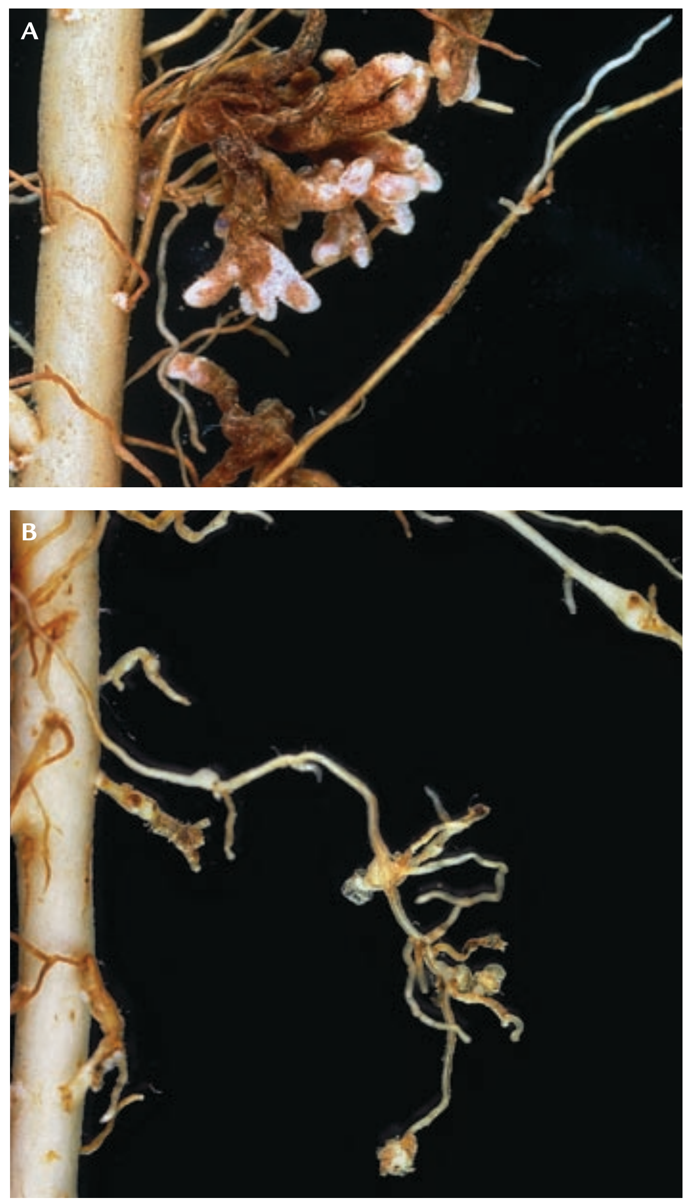


FIGURE 11.6

It is important to distinguish between the beneficial nodules (A) from bacteria that fix nitrogen for the plant, and those of root-knot galls (B) that result from parasitic root-knot nematodes on alfalfa.

wide host ranges, root-knot nematodes create problems for many susceptible crops that might be grown in rotation with alfalfa. In the San Joaquin Valley, perennial crops, such as trees and vines, are not susceptible to the root-knot species that infest alfalfa. Some vegetable and field crops may show damage if planted in a field following infested alfalfa or may increase root-knot nematode populations that might affect a subsequent alfalfa planting if a susceptible variety is planted.

The range of temperatures for development of southern root-knot, peanut root-knot (*M. arenaria* [Neal] Chitwood), and Javanese root-knot (*M. javanica* [Treub] Chitwood) nematodes is approximately 65–75°F (18–24°C), whereas the range for northern root-knot and Columbia root-knot (*M. chitwoodi* Golden, O'Bannon, Santo, and Finley, 1980) is approximately 41–77°F (5–25°C). Under these conditions, root-knot nematodes can complete a generation in 4–6 weeks and produce multiple generations per year. The pathogenic situation for Columbia root-knot nematode is further complicated by its having at least two morphologically indistinguishable races, only one of which is known to reproduce on alfalfa. The alfalfa race does not appear to be widely distributed in California.

Variety Resistance

Most varieties of dormancy classes 7–9 are resistant or highly resistant to the southern root-knot nematode. Fewer varieties are resistant to northern root-knot nematode. It is difficult to distinguish between these two species of root-knot nematode because they are very similar morphologically. If laboratory samples indicate the presence of root-knot nematodes but the species is not identified, choose a variety that has some resistance to both southern and northern root-knot nematodes. As a general rule, when planting on sandy ground, select a variety that has a high or at least moderately high level of resistance to root-knot nematodes.

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Stem Nematode

Stem nematode is known to attack over 450 plant species. However, there are at least 20 stem nematode biological races, some of which have a limited host range. This nematode was first identified in Germany in 1881 and was first reported in the United States in 1923. This species is believed to have been spread by debris in seed. When viewed under a microscope, these different races appear to be morphologically identical. They can only be distinguished by their host range (e.g., a race for alfalfa and a race for garlic and onions).

Infected plants will have shortened, stunted, and chlorotic stems (see Color Plates 11.1a and 11.1b). The nodes swell, and the internodes are short. These symptoms are associated with the release of digestive enzymes by the nematode and a resulting physiological imbalance of growth hormones produced by the plant.

This nematode is unusual because it spends none of its active life in the soil, but rather lives in the aboveground portion of the plant. The first larval stage remains in the egg, but subsequent larval stages and adults are able to infect developing alfalfa bud tissue. Optimum temperatures for invasion and reproduction in alfalfa are 59–68°F (15–20°C). Root nematodes reproduce in temperatures from 41–86°F (5–30°C). A life cycle can be completed in 19–23 days in susceptible cultivars; thus, multiple generations are possible in a single growing season.

Stem nematode is very sensitive to environmental conditions. Damage is most severe during moist, cool weather in cooler, sprinkler-irrigated inland valleys and foggy coastal areas. This species ranges as far south in the Central Valley as Madera County. Typically, damage is seen in the first and second cuttings. Hot, dry conditions later in the growing season reduce its activity. When environmental conditions are unfavorable for development, the fourth stage larva can serve as a desiccation-resistant survival stage in which the nematode's metabolism slows to an almost undetectable level. During such conditions, large numbers may survive in the crowns. When cool, moist conditions return, metabolic activity increases and development resumes. Typically, only small numbers of this nematode are found in the soil. Under favorable conditions, they will move in a film of water from the soil to crowns where young leaves and shoots are developing. They have been observed entering plants through stomata (minute openings in the epidermis of a plant through which gaseous interchange takes place).

Planting resistant varieties is the most effective control measure. Reduce the possibility of introducing this nematode into fields by planting certified seed and by cleaning equipment used for harvesting. If some fields are already infected, harvest them after harvesting healthy fields. Clean harvesting equipment between fields when you know a field is infested.

Management Techniques

There are few cost-effective treatments for existing infestations of nematodes in alfalfa. The key approaches to management include site selection, crop rotation, variety selection, and other management techniques that prevent nematodes from spreading. Determination of species and presence of nematodes is a key first step.

Sampling Techniques

Because there are few distinctive nematode diagnostic symptoms or signs, soil, root, and aboveground plant tissue samples should be taken and sent to a diagnostic laboratory when plant vigor seems limited without an apparent cause. To begin the procedure, visually divide the field into sampling areas that represent differences in soil texture, drainage patterns, or cropping history. Take a separate sample from each area so that each can be managed separately. Because nematodes are usually not uniformly distributed within a field, it is necessary to take a series of subsamples from throughout the area to accurately determine if nematodes are present. In a fallow field, samples should be collected randomly from the sample area. In an established field, collect separate subsamples from areas that show symptoms and from adjacent healthy areas.

It is usually better to sample at the edge rather than the middle of an unhealthy area because roots in the center of the area may be too decayed to support a good nematode population, compared to more healthy areas around the edge. Samples should include feeder roots, when possible, and be taken when soil is moist. Because most nematode species feed on roots, they are more prevalent in the rooting zone of the current or previous crop, and this is the area from which subsamples should be taken. Mix the subsamples together and place 1 quart of the mixed soil and roots in a plastic bag. Seal the bag, and place a label on the outside of the bag. Keep samples cool, but do not freeze, and transport as soon as possible to a diagnostic laboratory. Be certain that the laboratory knows that alfalfa is the current or planned crop for the field so that they will use appropriate extraction techniques.

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Treatment Thresholds

During recent years, increasing emphasis has been placed on the development and use of damage thresholds for making management decisions for pests. For many reasons, it is difficult to establish damage thresholds for nematodes. These include difficulties in obtaining representative samples, variability in extraction methods, efficiencies of different laboratories, and the many biotic and abiotic factors that influence populations. However, sampling periodically to determine if plant-parasitic nematodes are present can be very helpful in establishing the need for a nematode management program. If the nematodes discussed above as pathogens inhabit a field with below-normal growth and yield and no other explanation for the problem can be found, it is likely that nematodes are contributing to the problem. To determine if the nematode population is increasing or is remaining stable, a grower should sample an infested field at least once a year and at the same time each year.

Selection of Planting Site

Whenever possible, alfalfa should be planted in an area that is not infested with nematodes known to be pathogenic on alfalfa. Crop rotation can minimize populations if care is taken in the selection of crops planted between alfalfa crops. This is why proper identification of the nematode species present is so important.

Chemical Nematicides

Four chemicals are currently registered for preplant use on alfalfa in California: (1) 1,3-Dichloropropene (Telone II, 1,3-D), (2) chloropicrin, (3) metam-sodium (Vapam, Metam, Soil Prep, Sectagon, etc.), and (4) methyl bromide. However, because of their expense, fumigants are not likely to be a cost-effective control measure for plant-parasitic nematodes on alfalfa. There are no nematicides registered for postplant use on alfalfa in California.

Choice of Variety

A number of factors in addition to nematodes should be considered when choosing a variety (see Chapter 5, "Choosing an Alfalfa Variety"). From the standpoint of nematode management alone, varieties are available that are resistant to stem, northern root-knot, or to southern root-knot nematodes individually, but not to both pest species. The fact that multiple nematode resistance is not widely available means that it is important to determine the species of nematodes present in a field before choosing a variety. Confusion exists over the terminology used for defining nematode resistance in varieties of alfalfa and in processing tomatoes. Root-knot nematode resistant alfalfa tolerates the presence of root-knot nematodes but allows them to reproduce so that populations that could be damaging to a following crop will be present at crop termination. Root-knot resistant tomatoes, on the other hand, do not allow reproduction by southern, Javanese, and peanut root-knot nematodes, resulting in lower population levels at crop termination than at planting.

It is important to determine the species of nematodes present in a field before choosing a variety.

Certified Seed

It is important to buy only certified seed with a high level of resistance to minimize the chance of contaminating previously uninfested land. Until the importance of seed as a source of transmission of stem nematode was understood, as many as 17,000 nematodes were found per pound of alfalfa seed.

Clean Equipment

To minimize transfer of plant-parasitic nematodes, water should be used to remove soil and plant debris from farm equipment before moving equipment between fields.

Irrigation Water

Although growers might not have a choice of sources for irrigation water, they should be aware that surface irrigation water has been shown to be a potential source of nematode contamination. Whether there is a serious potential for contaminating alfalfa fields from irrigation water has not been determined. However, it is clear that runoff water from a known nematode-infested field should not be used to irrigate an uncontaminated field. In studies conducted in the state of Washington, more than a dozen different genera of plant-parasitic nematodes were found free floating in water samples taken from irrigation canals. Irrigating susceptible plants in a greenhouse with water from these infested samples resulted in nematode infestation. If a serious contamination problem is suspected, settling ponds can be used to reduce inoculum because most plant-parasitic nematodes will settle out within a short period, and nematode-free water can be pumped from the top of the pond.

Weed Management

Burning weeds within infested fields in the fall has been shown to decrease problems from stem nematodes the following spring. Conversely, for unknown reasons, experimental spring burning of weeds appears to make the nematode infestation problem worse.

Move Equipment on Dry Soils

Delaying cutting until the top 2–3 inches of soil is dry will minimize spread and reinfestation of stem nematode.

Crop Rotation

California crops, which have worked well in rotations for the race of stem nematode typically found on alfalfa, include small grain (wheat, oats, barley, triticale), beans, cotton, corn, sorghum, lettuce, melons, carrots, and tomatoes. A 3–4 year rotation is usually recommended. Care should be taken to destroy all volunteer alfalfa from previous crops. Otherwise, they will serve as a source of reinfestation after the rotation is completed.

Because of the wide host ranges of the species of root-knot nematode found in alfalfa in California, crop rotation is not usually a feasible method of managing this nematode.

Fallow

The length of time that many nematodes can survive in weed-free fallow soil is not known. For the stem nematode, survival in the absence of hosts depends on environmental conditions. It can be as short as 2 years in rotation to grain in areas of high rainfall or irrigation, or as long as 20 years in the dormant stage in fallow soil in areas with little rain.

Root-knot nematode populations are likely to decrease 80–90 percent within a year in fallow soil. However, until host roots or crowns and stems from a previous crop have rotted, they could continue to support nematodes.

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Biological Control

Many soils contain predators that attack nematodes, such as soil-dwelling mites and tardigrades, and even other nematodes. Also within soils are various types of parasitic fungi that may result in some level of natural biological control. It is estimated that naturally present predators and parasites may consume up to 95 percent of plant-parasitic nematodes inhabiting an environment, but those that are left are still enough to cause problems. There are no registered microbial nematicides.

Amendments

The addition of amendments to soil, such as green manures, chitin, sesame chaff, animal manure, humic acid, organic fertilizer, compost, and/or proprietary mixtures of beneficial microbials, is generally proclaimed to be beneficial to plant growth. With respect to nematode management, such benefits may include: (1) stimulation of the growth of nematophagous fungi (organisms capable of killing the nematodes); (2) improvements in soil structure, in water retention, and in plant nutrition that would reduce stress on nematode-infested plants; and (3) production of nematicidal (nematode-killing) breakdown products (e.g., high-glucosinolate rapeseed or broccoli residues, which decompose to produce compounds similar to the nematicide metam sodium). Because of the complex nature of the possible interactions, interpretation of results following addition of soil amendments is difficult. Sufficient data are not available to predict with any certainty the nematode mortality that might result with these materials. In some cases, the addition of amendments has resulted in phytotoxicity in some crops, thus a product should first be tested in a small area of the field. Also, it is possible that nematode populations could increase following application of an amendment that results in an improved root system. If the amendment results in reduced stress on the crop and the development of a healthier root system, this root system could support a larger nematode population. Leaving untreated areas for comparison to amended areas is a good method for judging the success or failure of soil amendments. Evaluation should include both nematode samples and plant yield.

An Integrated Approach

In general, a combination of management techniques provides the best nematode control. For example, a management program for stem nematode might involve the use of crop rotation, certified seed, use of a nematode resistant variety, fall burning of weeds, and washing equipment before and after use in each field. For root-infecting nematodes, yearly soil sampling can help growers interpret stress symptoms in a crop. A proper nutrition and irrigation program can help to reduce stress caused by nematodes. The use of soil amendments in portions of fields that can be compared to unamended areas might provide growers with additional management tools for their particular growing conditions. The best results can be expected when alfalfa is not suffering from other biotic and abiotic problems in addition to nematodes.

Additional Reading

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Color Plates

PLATES 11.1

(A) Stem-nematode damage. Note stunted plants and shortened internodes (middle/right) compared to normal plant (left). (B) Stem nematode injury in the field. Note stunted plants.

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