Alfalfa nematodes in Idaho

Saad L. Hafez

Plant parasitic nematodes are microscopic, worm-like animals that are commonly present in Idaho alfalfa fields. The three most common and economically important groups of nematodes on alfalfa in Idaho and the Pacific Northwest are the alfalfa stem nematode *(Ditylenchus dipsaci)*, root knot nematodes *(Meloidogyne species)*, and root lesion nematodes *(Pratylenchus species)*. These nematodes cause direct damage to alfalfa roots and stems, and nematode infection may also increase alfalfa susceptibility to plant pathogenic bacteria and fungi. Not only can nematodes reduce alfalfa hay and seed yield, but they can also impact other crops grown in rotation with alfalfa. Nematodes that are less common on alfalfa include pin, spiral, and stunt nematodes, and the alfalfa cyst nematode *(Heterodera trifolii)*. Some nematodes, such as the dagger, needle, and stubby root nematodes, are more important for the viruses they vector rather than for causing direct damage on alfalfa. This bulletin focuses on the three most common alfalfa nematodes in Idaho: the alfalfa stem nematode, root knot nematodes, and root lesion nematodes.

Plant parasitic nematodes are typically concentrated in root zones of plants, although a few species feed on above ground plant parts. Plant parasitic nematodes feed only on living plant tissues, thus they are obligate parasites. They possess a hollow needle-like structure known as a "stylet" that is used to puncture plant cells to draw plant cell contents to their intestine.

The nematode life cycle typically includes an egg stage, four larval stages, and an adult stage. Nematodes reproduce in three different ways: sexually (requiring individual males and females), hermaphroditically (in which an individual has both male and female reproductive organs), or parthenogenetically (requiring only females), depending on the species and environmental conditions. The life cycle, from egg hatching to egg production, usually requires three to six weeks under optimal conditions to complete. Environmental factors, such as soil temperature, soil moisture, host status, and time of infection, can influence the number of nematode generations within a year.

Nematodes move relatively short distances on their own (a few inches per year), but they are easily spread long distances by soil move-

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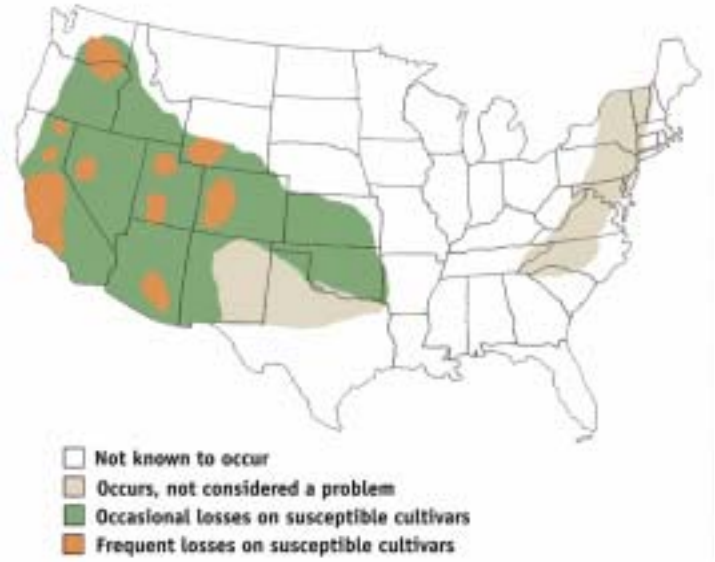

Figure 1. Distribution of the alfalfa stem nematode (*Ditylenchus dipsaci*) in the United States.

(Source: Standard Tests to Characterize Alfalfa Cultivars, NAAIC)

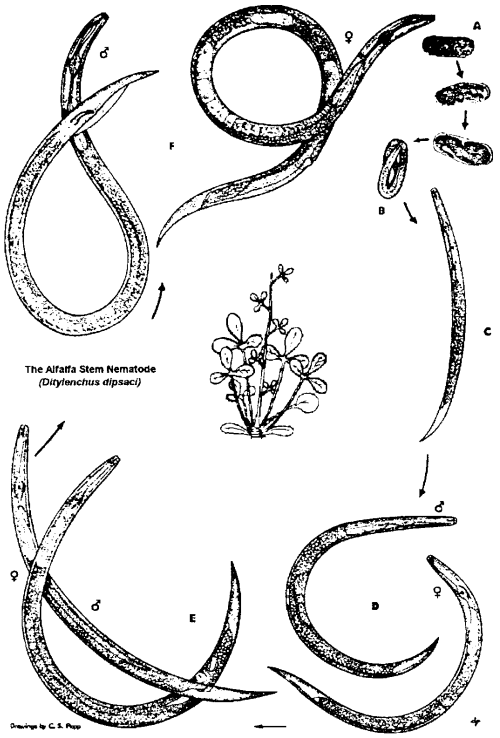

Figure 2. Life cycle of the alfalfa stem nematode (*Ditylenchus dipsaci*). A, egg; B, larvae within egg membranes; C,D, and E, second, third, and fourth stage larvae, respectively; F, mature adult male and female.

(Adapted from *Plant and Insect Nematodes.*)

ment (from tare dirt, wind, and farm equipment), irrigation water, nursery stock, seed, and debris in seed and hay.

1. Alfalfa Stem Nematode, *Ditylenchus dipsaci*

Distribution and host range

In Idaho and other northwestern states, the alfalfa stem nematode has been found in many alfalfa producing areas (Figure 1). It is the most serious yield-limiting nematode in Idaho and other alfalfa producing areas around the world. The alfalfa stem nematode prefers heavy soils and high water inputs (from rainfall or irrigation), and it is often found in areas where irrigation waste water is used. Although stem nematodes as a group parasitize more than 450 different plant species including alfalfa, garlic, potatoes, and beets, they occur in several biological "races" that have limited host ranges. The alfalfa race can parasitize several plant species but it reproduces only on alfalfa and seedlings of sainfoin (another legume hay). The alfalfa race apparently can also reproduce on potatoes, but not on onions.

Life Cycle, Survival, and Dissemination of the Stem Nematode

Stem nematodes are one of the few groups of nematodes that feed mainly on above ground plant parts and rarely on roots. After emerging from eggs, all stages of the stem nematode are able to attack the alfalfa plant (Figure 2). A mature female lives 45 to 73 days, reproduces sexually, and generate 200 to 500 eggs during her lifetime. Under average summer temperatures and adequate moisture conditions, the life cycle is completed in 19 to 30 days.

Although alfalfa stem nematode adults and eggs overwinter in succulent alfalfa tissue in the crown of the plant or in soil, the fourth stage larvae are the most likely to survive unfavorable conditions and re-infect plant tissue. The alfalfa stem nematode also overwinters in crop debris, seed, hay, and in association with susceptible weed hosts. Although stem nematodes can be found in soil, they usually enter the soil only if conditions become unfavorable in plant tissue. Compared to other plant parasitic nematodes, stem nematodes are unique in that they can withstand dehydration for long periods of time. The alfalfa stem nematode can be introduced into clean fields through uncleaned infested seed or other plant tissue (historically one of the most important means of stem nematode dissemination), contaminated manure and irrigation water, and harvesting equipment.

Figure 3. Field symptoms caused by stem nematode infestations include poor, stunted growth and thin stands.

Figure 4. Thin stands and bare patches of dead alfalfa caused by stem nematode infestations include poor, stunted growth and thin stands.

Symptoms Caused by the Stem Nematode

Field symptoms usually appear as patches of poor, stunted growth (Figure 3), and bare patches where weeds can invade (Figure 4). Nematodes that feed on plants in winter cause most of the damage, which becomes apparent the following spring through the following signs:

- Infested areas show poor growth in spring.
- Severely infected plants may die, and if wet weather persists, entire stands may be lost.
- Infected buds become swollen and distorted, and they are unable to elongate into normal stems (Figure 5). Depending on the variety, significant yield losses may occur due to shortened internodes.
- Under warm, humid conditions, alfalfa stem nematodes may migrate into the leaf tis-

Figure 5. Stem nematode-infected alfalfa stems have swollen, rotting buds at their crowns.

Figure 6. White leaves ("white flagging") is a symptom of alfalfa stem nematode infection.

sue and kill chloroplasts. The infected leaf tissue then turns white, and the resulting symptom is referred to as "white flagging" (Figure 6).

- Infection of the flower buds may lead to contaminated seed. Up to 17,000 alfalfa stem nematodes have been recovered from one pound of uncleaned seed.
- The alfalfa stem nematode occasionally feeds on roots, and root symptoms include internal cavities or gall-like outgrowths that may girdle the root crown.

The alfalfa stem nematode can vector the bacterial wilt pathogen, *Clavibacter michiganense* subsp. *insidiosum*, and has been implicated in breaking resistance to bacterial wilt in resistant or tolerant varieties of alfalfa. Alfalfa stem nematode can potentially cause more severe damage in the presence of other foliar fungal diseases, such as black stem and leaf spots.

Impact of Alfalfa Stem Nematode on Yield

Damage by the alfalfa stem nematode usually occurs before the first cutting during cool, humid weather. Nematodes in alfalfa stems may be removed with the first cutting, reducing the danger of infection during later cuttings. However, later cuttings may also become infected if soil is wet, since nematodes require water to migrate to infection sites.

Alfalfa varieties considered to be generally resistant to alfalfa stem nematode include Washoe, Lahontan, and Archer. Alfalfa varieties vary in their levels of resistance to alfalfa stem nematode. In a greenhouse evaluation conducted in 1986, four commercially available varieties of alfalfa (Apollo II, Lahontan, Ranger, and Washoe) and two experimental varieties were evaluated for their yield response to alfalfa stem nematode in greenhouse experiments. To measure dry matter, five cuttings were obtained throughout the duration of the experiment. Reductions in total herbage weight occurred for all varieties when they were inoculated with alfalfa stem nematode, but Washoe experienced the smallest yield loss (Table 1).

Management Strategies for Alfalfa Stem Nematode

	Average Yield Reduction (%)*	
Variety	**Stem Nematode**	**Northern Root-Knot Nematode**
Ranger	12.8 a	2.2 bc
EXP 49	7.3 b	-2.6 d
EXP 107	7.0 b	0.6 cd
Lahontan	7.7 b	5.5 a
Apollo II	7.1 b	0.3 cd
Washoe	5.5 c	4.2 ab

*LSD (0.10) was used for mean separations. Values within columns followed by the same letter are not significantly different.

Table 1. The effect of alfalfa stem nematode or Northern root knot nematode on yield reduction of different alfalfa varieties. Data represents weighted means of five dry matter yield cuttings under greenhouse conditions (Parma, ID 1986).

a. Resistant varieties.

Planting varieties with high levels of resistance, such as Archer, Lahontan, and Washoe, is probably the best management tool available, especially when alfalfa is grown on irrigated land. It has been suggested that without some level of stem nematode resistance, alfalfa production would be seriously threatened in many areas.

b. Prevention (sanitation and exclusion).

- Use clean, nematode-free seed.
- Avoid moving contaminated farm machinery or livestock from an infested field to a clean field.
- Avoid using contaminated waste water or tail water.
- Keep manure from feedlots where cattle have been fed infected hay out of clean fields.

c. Cultural practices.

- Fall burning (in alfalfa seed production systems) decreases nematode infection and mortality, but spring burning appears to enhance infection and increase plant mortality.
- The alfalfa stem nematode is a biological "race" of stem nematodes, and its host range is very limited. Consequently, rotation with nonhost crops such as sorghum, small grains, beans, and corn on a 2– to 4–year basis should reduce alfalfa stem nematode populations. Be careful to avoid re-infesting the field with contaminated irrigation water or machinery. Eliminating old and volunteer alfalfa plants through a weed control program is also important to avoid re-infestation.
- Cutting alfalfa fields only when the top 2 to 3 inches of soil are dry should help reduce reinfection. University of Idaho variety trials demonstrate that frugal applications of irrigation water to keep soil surfaces dry will minimize spread into later cuttings.

d. Chemical control.

- No nematicides are registered for use against the Alfalfa stem nematode.
- Fumigation before planting may be costly relative to potential economic benefits.

2. Root knot nematodes, *Meloidogyne species*

Distribution and Host Range

Root knot nematodes are among the most widespread and economically important of plant parasitic nematodes. In Idaho, two species of economic concern are the Northern root knot nematode (*M. hapla*) and the Columbia root knot nematode (*M. chitwoodi*). The Northern root knot nematode is distributed throughout Idaho and the United States (Figure 7), while the Columbia root knot nematode occurs in the Columbia River Basin of Washington and Or-

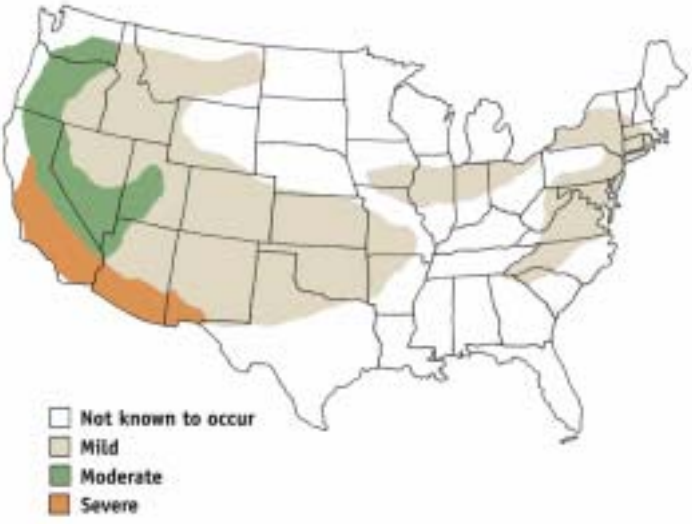

Figure 7. Distribution of the root knot nematodes (*Meloidogyne* species) in the continental United States.

(Source: Standard Tests to Characterize Alfalfa Cultivars, NAAIC)

egon, in Idaho and northern California, and in parts of Nevada. Though found in most soil types, they are most abundant in sandy loam soils. Root knot nematodes on alfalfa are of economic concern partly for the direct damage they can cause, but more importantly for the serious damage they inflict on high value susceptible crops that are grown in rotation with alfalfa, such as potato, sugarbeet, and bean.

Root knot nematodes have wide host ranges. The Northern root knot nematode attacks more than 550 different hosts, including alfalfa. Grain crops, however, are poor hosts for the Northern root knot nematode. In contrast, grains (specifically, wheat and barley) **are** hosts for the Columbia root knot nematode. Two races of the Columbia root knot nematode, race 1 and race 2, occur in Idaho, but only race 2 is able to reproduce on susceptible alfalfa varieties.

Other species of root knot nematode that are plant parasitic on alfalfa (*M. arenaria, M. incognita,* and *M. javanica*) do not survive in Idaho because they are not adapted to low winter temperatures.

Life Cycle, Survival, and Dissemination of Root Knot Nematodes

Unlike the stem nematode which infects plant tissue during all stages in its life cycle, root knot nematodes are infectious only when they are newly hatched second stage juveniles (Figure 8). After entering the root, second stage juveniles undergo three more molts. As the alfalfa seedling develops, second stage juveniles which penetrated root tissue become es-

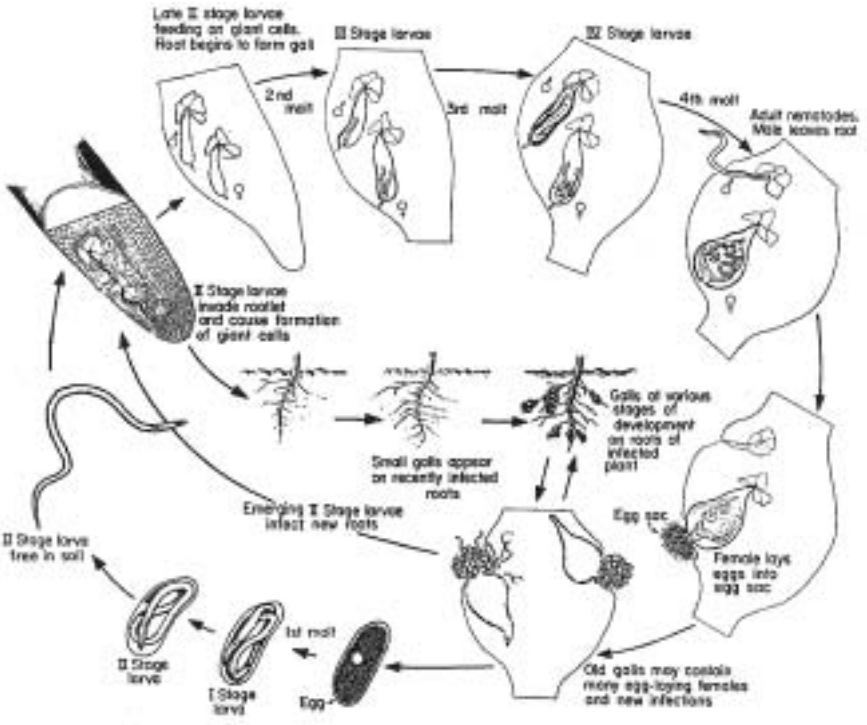

Figure 8. Life cycle of root knot nematodes.

tablished and sedentary in the cortical tissue. Feeding of the nematode initiates a series of host responses, culminating in the formation of galls, and giant plant cells within the galls provide food for the nematodes. As females mature, their bodies swell and they remain immobile. Pearly white swollen females, about the size of a pinhead, can be seen. Root knot nematodes reproduce sexually, and mature females deposit 50 to 1,000 eggs in a gelatinous matrix within root tissue. Males maintain their long and slender body, and after the fourth molt, they are once again mobile. Under ideal conditions, the life cycle of root knot nematodes is usually completed in 20 to 25 days, and four to five generations may occur in one growing season. For *M. hapla,* the life cycle on alfalfa takes approximately 30 days at 77°F. Root knot nematodes overwinter as second stage juveniles and as eggs in the soil. They may also survive as egg masses in root tissue from the previous crop.

Symptoms Caused by Root Knot Nematodes

Infection of alfalfa by *Meloidogyne* species may be confined to localized areas of a field or extend throughout an entire field. The extent of the damage in the field depends on several factors, including initial nematode population level, alfalfa variety, and soil temperature at planting time. High initial populations and warm soil temperatures may cause serious injury to seedlings, resulting in stunting.

The Northern root knot nematode infects and parasitizes roots of alfalfa plants and causes the plant cells to enlarge into small oval galls on the roots that can be seen with the naked eye (Figure 9). Galls caused by root knot nematodes are accompanied by lateral root growth, unlike galls caused by the beneficial nitrogen-fixing bacteria. In a heavily infested field, young seedlings may be killed by this nematode, even though roots may not display galls. The Columbia root knot nematode (race 2) produces similar symptoms as the Northern root knot nematode, but it is less pathogenic to alfalfa, and they cause tiny galls that can easily be missed if roots are not examined carefully.

Root knot nematodes, like stem nematodes, are implicated in interactions with other pathogens. Bacterial wilt, Phytophthora root rot, Fusarium wilt, and damage by the alfalfa stem nematode may be enhanced on alfalfa when the Northern root knot nematode is present.

Figure 9. Healthy plant (right) and plant infested by the Northern root knot nematode *Meloidogyne hapla* (left), showing excessively branched roots with small galls.

Impact of Root Knot Nematodes on Yield

A greenhouse experiment was conducted to evaluate the response of four commercial alfalfa varieties and two experimental varieties to infection by the Northern root knot nematode. Dry matter weight data were obtained for each variety from inoculated and non-inoculated plants, and five cuttings were taken over the course of the experiment. Results suggest that yield reductions are influenced by cultivar resistance levels (Table 1).

In a separate greenhouse experiment, the effect of various commercial alfalfa cultivars on population density of the Columbia root knot nematode was evaluated. Lobo, Archer, and Nevada Syn-XX reduced populations of the Columbia root knot nematode by 92, 89, and 77 percent, respectively, compared to the susceptible cultivar Lahontan.

Management of Root Knot Nematodes

1. Resistant varieties.

Use of resistant alfalfa varieties is probably the most practical means of managing root knot nematodes. A number of resistant varieties are now commercially available.

2. Crop rotation.

Crop rotation to manage the root knot nematode is not successful because of the wide host range of these nematodes.

3. Chemical control.

Soil fumigation before planting can be effective against the Northern root knot nematode. However, fumigants are expensive and they are generally not economically feasible on alfalfa. No non-fumigant nematicides are currently registered on alfalfa.

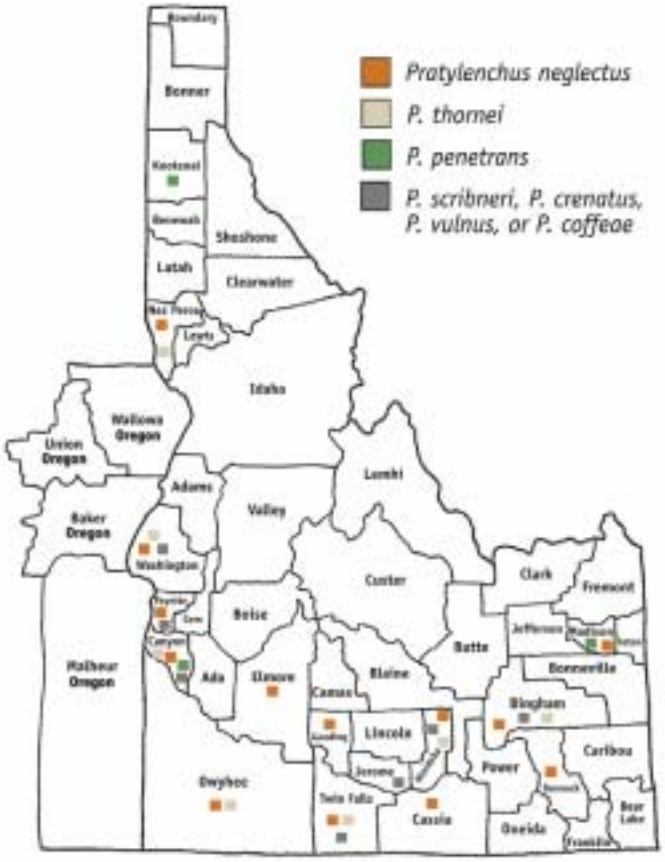

Figure 10. Distribution of lesion nematodes (*Pratylenchus* species) in Idaho.

(Data based on soil samples received by the University of Idaho Nematode Diagnostic Laboratory, Parma, Idaho).

3. Root Lesion Nematodes, *Pratylenchus* species

Distribution and Host Range

Root lesion nematodes are found throughout the world in temperate and tropical regions. Like root knot nematodes, lesion nematodes have a wide host range that varies from crops to weeds, and they are most destructive to roots of cultivated and non-cultivated plants in sandy or sandy loam soils. Many species of root lesion nematodes are associated with alfalfa. The most economically important species of lesion nematode is *Pratylenchus penetrans*, but this species is relatively uncommon in Idaho. The most common species in Idaho are *P. neglectus* and *P. thornei* (Figure 10).

Life Cycle, Survival, and Dissemination of Root Lesion Nematodes

Pratylenchus species are migratory, endoparasitic nematodes that can invade plant roots at all stages of the life cycle outside the egg (similar to the stem nematode) (Figure 11). As in the stem and root knot nematodes, second stage juveniles of root lesion nematodes emerge from eggs (nematodes typically undergo their first molt inside the egg). Lesion nematodes penetrate the entire root system, except root tips, by forcing their way between or through epidermal and cortical cells. They feed on cell contents as they migrate within roots. Females deposit eggs in root tissue or soil, and the eggs in plant tissue or in soil survive winters. Females do not survive winters in Idaho. The most important method of dissemination of root lesion nematodes is probably contaminated irrigation water, machinery, or tare dirt.

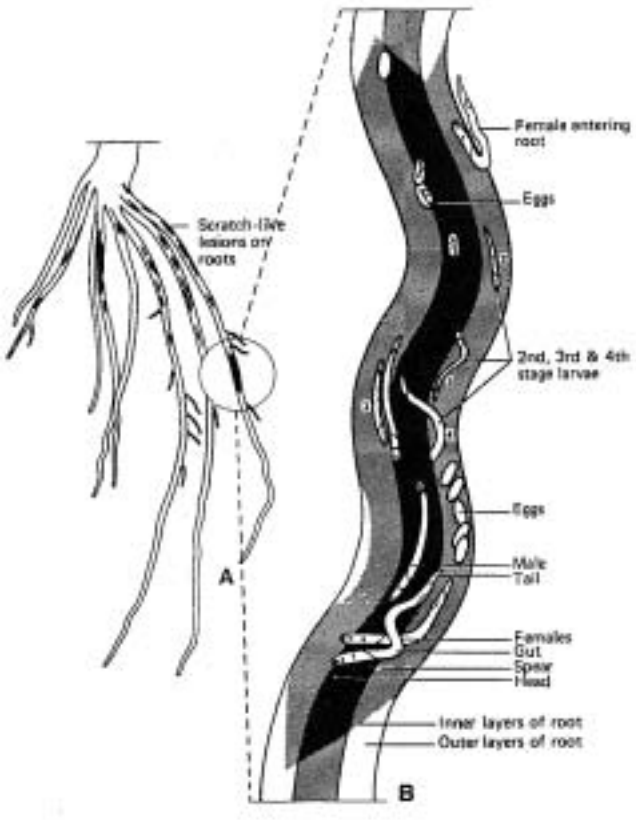

Figure 11. Diagram of the alfalfa root system with root lesion nematodes: (A), dark lesions on roots; (B), an enlarged lesion illustrating all stages of the life cycle.

Symptoms of Root Lesion Nematodes

Plants infected with root lesion nematodes do not show above ground symptoms that can positively aid in nematode identification. Aboveground symptoms are more general, and can include stunting and nutrient deficiencies. Root lesion nematodes reduce root growth and inflict black or brown lesions on the root surface (Figure 12). Lesions may fuse to cause the entire roots to appear brown. Secondary infections of roots by other bacterial and fungal pathogens commonly occur after root lesion nematode invasion. Alfalfa resistance to these secondary pathogens may sometimes be overcome due to root lesion nematode invasion.

Figure 12. Healthy alfalfa root system (right) and roots infected with P. penetrans showing black and brown lesions (left).

Impact of Root Lesion Nematodes on Yield

In a greenhouse experiment conducted at Parma, three commercial varieties and two experimental varieties were evaluated for their response to root lesion nematode infection. Variety dry matter weights were obtained from inoculated and non-inoculated plants. Five cuttings were taken over the course of the experiment. Root lesion nematode significantly reduced dry matter for all varieties compared to non-inoculated treatments (Table 2). However, yield reductions for the experimental varieties were lower than three commercially available varieties (Baker, Ranger, and Nevada Syn-XX). The development of alfalfa varieties that display root lesion resistance and agronomically desirable characteristics is on-going.

Variety	Average Yield Reduction (%)*
AP 8831	16.1 b
AP 8821	15.0 b
Baker	23.1 a
Ranger	22.0 a
Nevada Syn-XX	23.1 a

*LSD (0.10) was used for mean separations. Values followed by the same letter are not significantly different.

Table 2. The effect of lesion nematode, *Pratylenchus penetrans*, on foliar weight of different alfalfa varieties under greenhouse conditions.

Management of Root Lesion Nematodes

1. Crop rotation.

Because lesion nematodes have a wide host range, and more than one species may occur in a field, crop rotation is not effective for lesion nematode management. However, leaving a field fallow, followed by treatment with a nematicide, can reduce lesion nematode populations.

2. Resistant varieties.

Scientists in Idaho and Minnesota have identified and developed alfalfa germ plasm with resistance to lesion nematodes. However, alfalfa varieties with adequate resistance are not yet commercially available. When varieties with satisfactory resistance to one or more *Pratylenchus* species become available, they will probably be the best means of controlling lesion nematodes since the cost of chemical control is prohibitive.

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