# Nematodes

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Nematodes are roundworms, similar to the animal parasites encountered in livestock and pets. Soil-dwelling nematodes are both beneficial and harmful in crop production. The good nematodes, which don't get much press, feed on fungi, bacteria, other nematodes, and other creatures that live in the soil and thereby recycle the nutrients contained in it (Figure 15.1). The presence of some of these types of "good" nematodes can be used as an indication of soil health. Tens of millions of mostly beneficial nematodes live in each square meter of cropland; however, a few of these microscopic roundworms—the plant-pathogenic nematodes—give all nematodes in crop production a bad name. This chapter addresses the most important plant-pathogenic nematodes in Illinois agriculture.

## How nematodes damage plants

Plant-pathogenic nematodes feed only on plants; in fact, without the proper plant host(s), they die. When their numbers increase to high levels, they can severely injure or kill plants, especially seedlings (Figure 15.2). In lower, more typical numbers, they can suppress crop yields without causing obvious symptoms, and they can be involved in disease interactions with other pathogens, including viruses, fungi, and bacteria. Virtually every field has one or more potentially damaging nematode species. The probability for causing disease depends on several factors:

- the species and the number of nematodes in the field
- crop history, especially whether susceptible crops have been grown in the field in the past
- environmental factors, particularly those influencing the soil environment, such as moisture and temperature

Most of the plant-pathogenic nematodes (referred to simply as nematodes from here) feed on plant roots, although some less common ones feed in various aboveground plant parts. The root-feeding nematodes are either ectoparasites (Figure 15.3), which feed from outside the roots, or endoparasites (Figure 15.4), which feed from inside the root.

Fig. 15.1. Nematodes extracted from the soil, which include bacterivores, fungivores, omnivores, predatory, and plant-parasites (Photo courtesy of Dr. Lesley Schumaher, USDA-ARS).

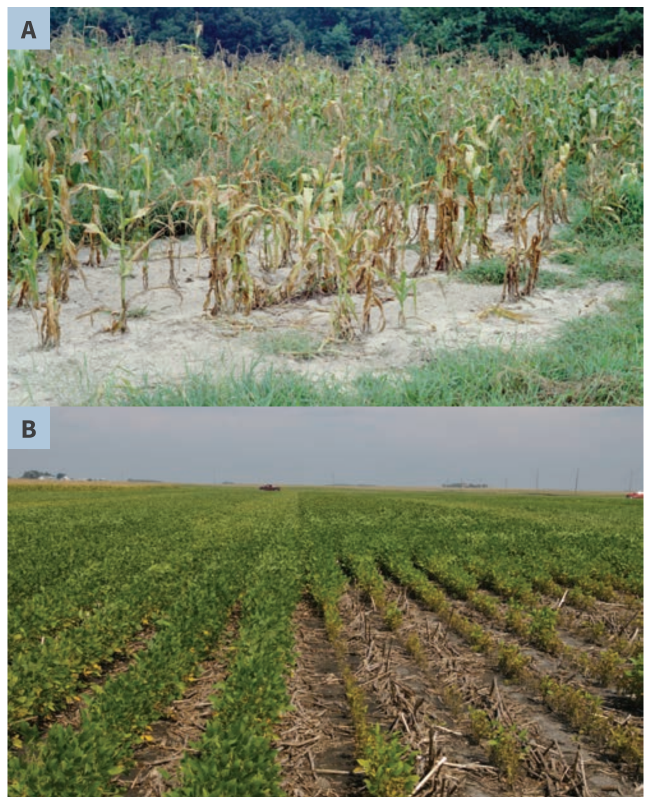


Fig. 15.2. A) Severe nematode damage in a corn field caused by sting nematode (Belonolaimus sp.) (image: Clemson University-USDA Cooperative Extension Slide Series, Bugwood.org), B) severe nematode damage in a soybean field caused by soybean cyst nematode (Heterodera glycines) (image: Craig Grau, Bugwood.org)

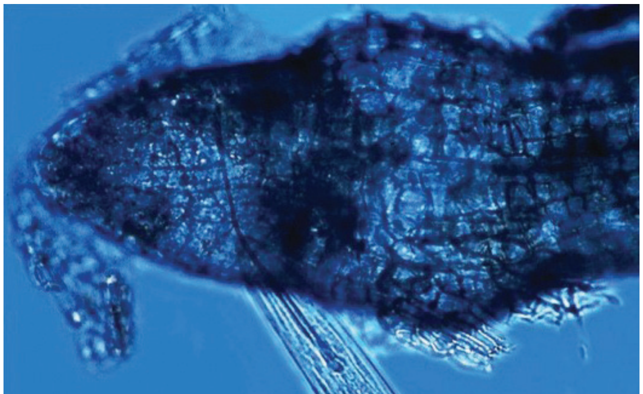

Fig. 15.3. An ectoparasitic nematode (bottom center feeding on a root tip). (Photo courtesy of the Society of Nematologists)

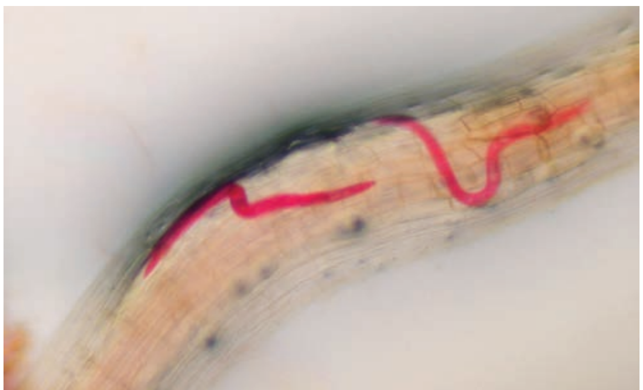

Fig. 15.4. An endoparasitic nematode (stained fuchsia) feeding within the soybean root (image: Connie Tande, SDSU Plant Science Dept., Bugwood.org)

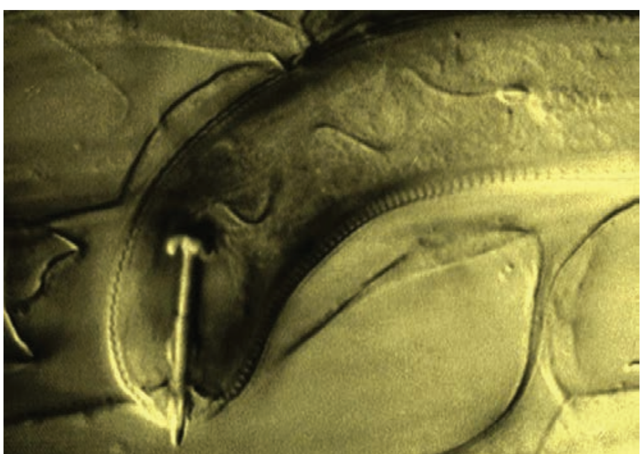

Fig. 15.5. Close-up of the head of a root-feeding nematode. The stylet tip (not visible in this photo due to the head cap) is similar to a hypodermic needle in that its opening is on one side of the point. The rounded knobs at the base of the stylet anchor muscles extending forward to the head. When these muscles contract, the stylet protrudes, and the nematode can take in plant material, inject secretions, or both. (image: Mactode Publications, Bugwood.org)

All plant-feeding nematodes feed by means of a stylet (Figure 15.5), a structure in the head of a nematode that allows it to pierce plant cell walls. The stylet tip (not visible in the figure) is like a hypodermic needle in that its opening is on one side of the point. The rounded knobs at the base of the stylet (not present in all plant-feeding nematodes) anchor muscles extending forward to the head. When these muscles contract, the stylet protrudes, and the nematode can take in plant material through the stylet, inject secretions, or both.

Although some ectoparasitic nematodes, such as needle nematode, can be devastating to crop plants, the endoparasitic types are generally much more damaging in terms of economic losses. Endoparasitic nematodes spend most of their lives within plant roots, interfering with root structure and function. In Illinois, the most important endoparasitic species are the cyst, root-knot, and lesion nematodes (covered on pgs. 5-10).

## Scouting for Nematodes

With the single exception of root-knot nematodes, which cause characteristic galling on plant roots (Figure 15.6), root-feeding nematodes do not cause specific symptoms. Stunting and chlorosis (yellowing) are the most common visible symptoms of nematode parasitism, but symptoms like these (Figure 15.7) may be caused by any number of biological or abiotic factors.

If a field does not produce the yields that could reasonably be expected based on all inputs and growing conditions, high numbers of root-feeding nematodes

Fig. 15.6. Soybean roots showing symptomatic galling indicative of infection by the root knot nematode (Meloidogyne sp.) (image: Edward Sikora, Auburn University, Bugwood.org)

Fig. 15.7. Early-season symptoms of soybean cyst nematode infection (and perhaps other factors) include stunting and yellowing. (Photo courtesy of A. Wrather.)

should be considered as a likely cause of yield loss. There is only one way to determine whether a nematode problem exists in a field: sample the soil.

## How to sample for nematodes.

First, you must first decide the purpose of the sampling in order for sampling to be effective.

- for research purposes, sampling must be intensive, and each sample must represent a very small area of land. A typical field research plot ranges from 1 to 50 square meters.
- for detection purposes, that is, to determine whether a particular nematode is present in high enough numbers to cause crop damage—each sample must represent no more than 10 acres. If a "hot spot" (an area with visible crop damage; see Figure 15.8) is present, the soil samples taken should include the edges of the hot spot but not the center. At the center, root damage may have been severe enough that the remaining roots are not able to support a nematode population.

Fig. 15.8. A "hot spot" in a soybean cyst nematode– infested field, showing symptoms of nematode infection (image: Albert Tenuta, Ontario Ministry of Agriculture, Food and Rural Affairs, Bugwood.org)

- for monitoring purposes, that is, to assess the effects of nematode management practices over time, the size of the sampled area should be relatively small, perhaps an acre. This sampling area should be representative of the whole field in terms of soil type, topography, and treatments. The sampling are should be marked, or the GPS coordinates recorded, so that the area can be resampled over a period of years.

Because sampling purposes differ, the sampling area represented in Figure 15.9 can range in size from 1 square meter to 10 acres.

Second, prepare a soil sampling kit. The kit should contain the following items:

- a tool with which to take several samples of soil—preferably a soil probe that is 1 inch in diameter, or a shovel or trowel (Figure 15.10)
- a bucket (Figure 15.10)
- 1-quart-capacity plastic zipper-style bags, or larger (Figure 15.11)
- a permanent marker (Figure 15.11)
- a small cooler

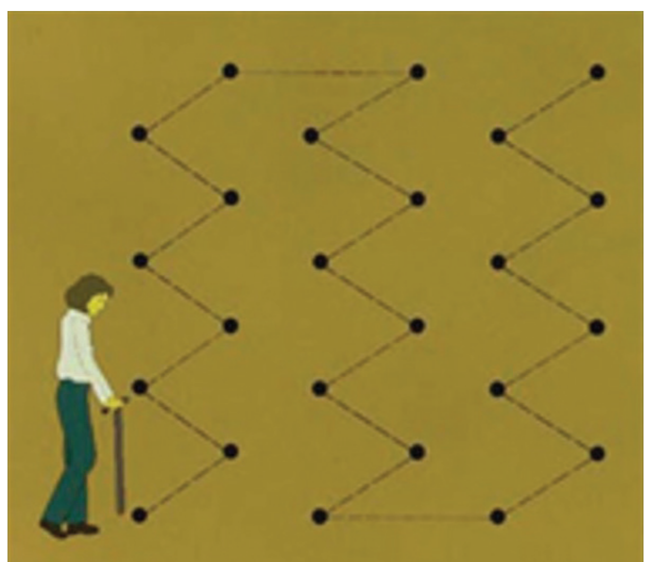

Fig. 15.9. A zigzag sampling pattern for an area that can range in size from 1 square meter to 10 acres. (image: Iliinois Agronomy Handbook, 2009 Edition)

Fig. 15.10. Tools recommended for soil sampling for soybean cyst nematode: soil-sampling probe, screwdriver to remove soil from the probe, and bucket to bulk individual cores. (image: Illinois Agronomy Handbook, 2009 Edition)

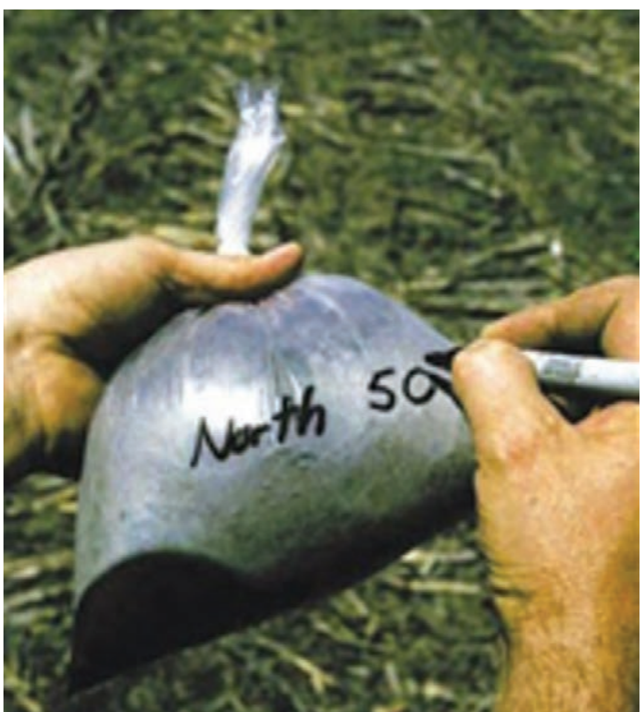


Fig. 15.11. Tools recommended for soil sampling for soybean cyst nematode: quart-size plastic bags and permanent marker. (image: Illinois Agronomy Handbook, 2009 Edition)


Fig. 15.12. A) After all cores are collected for a sample, B) the soil should be mixed gently but thoroughly (image: Mactode Publications, Bugwood.org).

Third, sample the plot or field in the following manner:

- Take 20 to 30 subsamples (represented in Figure 15.9 as black dots) in a zigzag pattern throughout the area to be sampled.
- Each subsample should be taken to a depth of 8 to 12 inches. The top inch may be discarded. (Sampling for certain nematodes, such as needle nematode, may have to be much deeper depending on the time of year and soil moisture.)
- Place all subsamples in a bucket as they are taken. After all subsamples are collected, mix the soil ***gently but thoroughly*** to break up clods (Figure 15.12).
- Lightly fill a 1-quart plastic bag with the mixed soil and discard leftover soil.
- Use a permanent marker to write an identifying label on the plastic bag. Use any words or numbers that will allow you to identify the source of the sample later (Figure 15.11).

Fig. 15.13. Soil samples prepared for shipping or trans- port to the lab, in a cardboard box cushioned with newspaper to reduce drying, heating, and rough treatment, which can damage the nematodes and interfere with the lab's ability to recover them. (image: Illinois Agronomy Handbook, 2009 Edition)

- Place the sample in a cooler and keep it out of heat and sun until it can be sent to a lab for analysis. Store in a fridge if available until able to ship it.
- If the sample is to be shipped, pack it in a cardboard box cushioned with newspaper or some other insulating material (Figure 15.13). Aim to ship the sample on a Monday or Tuesday to avoid the sample from sitting in a hot truck over the weekend. Drying, heating, or rough treatment of the sample can render it useless for analysis.

# Soybean-Parasitic Nematodes

### Soybean Cyst Nematode

The soybean cyst nematode (SCN) is the most important soybean pathogen in Illinois, causing more than $200 million in losses to producers each year. SCN can be found in more than 80% of the soybean fields in Illinois and is present in every county within the state. SCN remains a problem year after year because, in most infested fields, yield suppression occurs without any visible symptoms, such as stunting, chlorosis (yellowing), or "sick-looking" plants (Figures 15.7 and 15.8). SCN can cause up to 30% yield suppression before any aboveground symptoms show up. If soybean yields do not meet expectation in a given field or area within a field, SCN should be the first suspected cause even if plants look healthy.

**Life cycle**. SCN survives from one year to the next in eggs that are contained within cysts in the soil. Each cyst can contain up to 200 eggs (Figure 15.14). If a nonhost crop, such as corn, is planted, only a few of the eggs will hatch, with the others remaining dormant until soybean (or another susceptible crop) is planted. Soybean yield suppression is dependent on the number of eggs in the soil because the juvenile worms that invade the roots hatch from these eggs (Figure 15.15).

Fig. 15.14. A cyst, broken open to expose the eggs and juveniles within. (Photo courtesy of E. Sikora.)

Fig. 15.15. Soybean cyst nematode juveniles after hatching: the infective stage. (image: Illinois Agronomy Handbook, 2009 Edition)

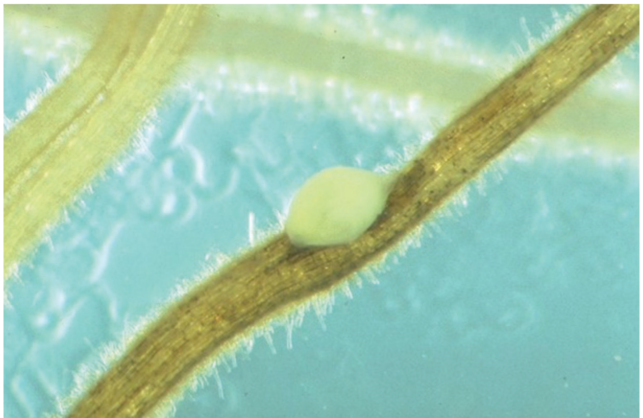

Fig. 15.16. female soybean cyst nematode on soybean root. (Photo courtesy of G. Tylka.)

Fig. 15.17. Soybean cyst nematode females (small white bodies) on the roots of a soybean plant. (Photo credit: Greg Tylka, Iowa State University, Bugwood.org)

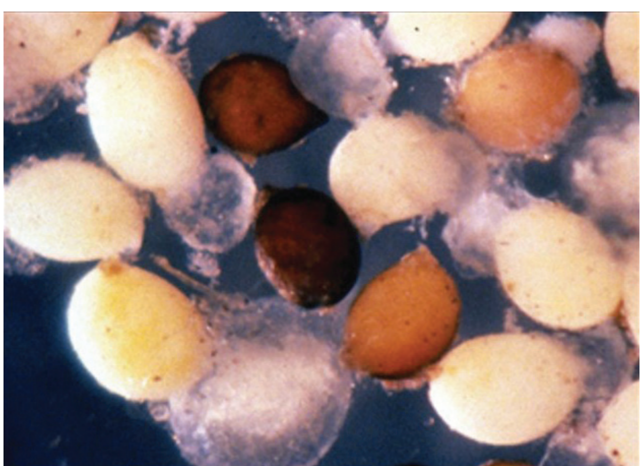

Fig. 15.18. Color change of soybean cyst nematode cysts as they age. White females are young and actively producing eggs; brown cysts are dead females containing eggs that can remain viable for many years. (image: Illinois Agronomy Handbook, 2009 Edition)

SCN juveniles, sometimes called "larvae" in old texts, enter soybean roots and migrate to the vascular tissue, where they inject saliva between and into cells. The saliva contains enzymes and other compounds (many still unidentified) that cause the injected cells and their neighbors to form a feeding site, a system of giant cells known as a syncytium. Because of their location in the vascular tissue, syncytia interfere with normal root function. The syncytia also function as "transfer cells," transferring photosynthetic products from the leaves, much as normal transfer cells do in other metabolically active parts of the plant. In this way, the nematode can compete with the seeds for photosynthate and can reduce yields without causing the plants to look unhealthy. If SCN numbers are high, however, the nematodes can interfere with root function and outcompete normal plant parts so that plants become stunted and chlorotic.

While inducing and maintaining their syncytia, the juveniles do not move from the feeding site. Following several molts, the nematodes become adults. Half of the adults are males. The male nematodes regain their original worm shape (although they are much longer) and exit the root system. The other half become females (Figure 15.16). Adult females are unable to move because of their large lemon-like shape and lack of muscle. Females become so large that they protrude from the root and can be seen, when they are young, as white spheres (Figure 15.17).

Females turn yellow and then brown (Figure 15.18) as their cuticle (skin) hardens and melanizes while they lay eggs, and they can no longer be seen without a microscope. Brown females are known as cysts, hence the name soybean cyst nematode, and the hardened cuticle that is the cyst serves as a durable protective barrier to the many eggs that remain within the female's body. The whole life cycle takes only 28 days in a greenhouse under optimal conditions. In the field, it may take as long as 6 weeks.

**Management.** There are currently no recommended chemical control options for SCN in Illinois. Although some products are labeled for use, using them is not an economically viable approach.

You cannot get rid of SCN once it infests a field. Some of the eggs within cysts can remain viable for at least 12 years, even when a susceptible crop is never planted.

However, yield losses caused by SCN can be reduced by the rotate-rotate-rotate system:

- Rotate with a nonhost crop, such as corn.
- Rotate with SCN-resistant varieties.
- Rotate sources of resistance in soybean varieties. Never grow the same SCN-resistant variety in the same field two soybean years in a row. No variety is completely resistant to SCN, and adaptation to resistance can occur quickly. Avoid this "HG-type shift" problem by changing resistant varieties every time you plant soybean.

Monitor SCN-infested fields over time. Most fields do not need to be sampled more than once every 6 years (3 soybean years). In the fall before soybeans are planted the following spring, submit a soil sample from each field to a qualified lab for analysis. In Illinois, overwinter survival of SCN approaches 100%, so the number of nematodes present in the fall is highly predictive of the number that will be present at planting in the spring.

**Commercially available SCN resistance.** Since the integration of SCN resistance into commercially available cultivars after success in breeding programs, one source of resistance has become most prevalent. (A "source of resistance" refers to the original resistant parent in a pedigree; sources include seven plant introductions [PI] included in the USDA National Soybean Germplasm Collection, which happens to be located on the Urbana campus of the University of Illinois.) Resistance derived from the plant introduction [PI] 88788 source of resistance makes up more than 90% of the varieties with SCN resistance available on the market.

The other source of resistance that has been around for some time is from Peking. A new source of resistance released in 2021 is derived from PI 89772. This brings more options as far as rotating sources of resistance in fields known to have problematic SCN population densities. However, in 2021 the only maturity group that this source of resistance was available in was a 2.3, which limits the utility of this source of resistance for now. Keep an eye out for this source of resistance in different maturity groups that can be used throughout more areas of Illinois in the future.

**HG type shifts.** The HG type of a soybean cyst nematode population is simply a way of phenotyping (or characterizing) the population's potential to cause damage on soybeans with different sources of resistance. In the HG type test, the seven SCN indicator soybean lines (sources of resistance) are grown in a soil sample submitted to the University of Illinois Plant Clinic. The HG type is determined by assessing the number of SCN females that develop on the indicator lines compared to a known SCN-susceptible soybean cultivar. This test is a good way to observe shift in SCN population phenotypes over time but may provide more information than a grower or crop adviser needs.

If SCN numbers appear to be increasing in a field that has been managed by rotation of resistance, it is likely that a so-called HG type shift has occurred. What this means is that the population of nematodes in the field have adapted to resistant cultivars that have been grown in that field, and they may be causing yield suppression even though the cultivar is labeled "resistant." This example is not far from reality, as most commercially available soybean varieties with SCN resistance are derived from one source: PI 88788. Furthermore, most soybean varieties on the market come with SCN resistance whether seeking it or not. So, with the repeated used of PI 88788 in soybean production throughout Illinois, it is likely that this source of resistance is no longer as effective at managing SCN populations in the state.

In this case, the best way to plan a management strategy is to start with an "SCN type" test, which is an abbreviated version of the HG type test that uses only sources of resistance that are commercially available, thus, making the results more relevant to growers in Illinois. This test can is done by the Plant Clinic at the University of Illinois (1102 S. Goodwin Ave., Urbana IL 61801, go.illinois.edu/plantclinic). This test will determine the extent of the population shift and help the grower devise a management plan.

There are some SCN types of concern in Illinois because of the historic reliance on a single source of SCN resistance, PI 88788. SCN Type 0 cannot parasitize any of the sources of resistance; therefore, any resistant cultivar may be used to manage this type. The SCN types of concern include:

- SCN Type 2 can parasitize PI 88788, which is the most common source of resistance in cultivars available in Illinois. If the SCN population has shifted to Type 2, then a cultivar with resistance to Peking or PI 89772 should be used for one season.
- SCN Type 1.2. can parasitize both PI 88788 AND Peking sources of resistance. These are the two sources of resistance that are most readily available in Illinois. It will be important to rotate to a soybean variety with resistance derived from PI 89772 for one season, in a rotation of all commercially available sources of resistance. However, this source of resistance is only available in one maturity group as of 2021. Keep an eye out for this PI 89772 source of resistance to become more accessible to other growing regions throughout Illinois.

According to results from an HG type survey conducted for three years from 2018-2020, the PI 88788 source of resistance is no longer as effective as it should be on all the SCN populations in that were surveyed. Additionally, about 10% of populations surveyed could effectively parasitize Peking. With three sources of resistance that are commercially available, rotating sources of resistance should become easier to do and even more effective. Be cognizant of the SCN resistance in the soybean varieties you select the grow and ensure that the sources of resistance are not the same in every soybean year.

**Disease interactions.** SCN infection causes stress for plants, which can increase a crop's susceptibility to nutrient deficiencies, water stress, and pathogens. Diagnosis of soybean disease problems in Illinois should always include an assessment of SCN, because the nematode is common and is likely to be involved, at the very least as a stress factor. Samples that are submitted to the plant clinic should include some whole plants that include roots on which trained diagnosticians can look for SCN. Take care of the SCN problem first to reduce crop stress.

SCN is directly involved in the development of certain soybean diseases. Sudden death syndrome (SDS) and brown stem rot (BSR) are the most important of these diseases in Illinois (see pgs. 12-15 in Chapter 14 Managing Diseases). The exact nature of SCN involvement with SDS and BSR is not known, but when either disease occurs in a field, SCN is likely to be present. Soybean varieties with resistance to BSR and SCN, or tolerance to SDS and resistance to SCN, are available, and these varieties should be used when appropriate.

**Seed treatments for SCN**

There are a lot of seed treatments on the market that are labelled to help control SCN (Table 15.1). The active ingredients vary from chemical compounds like abamectin or fluopyram, to a variety of biological agents. The efficacy of seed treatments at mitigating yield suppression from SCN is highly variable. Remember, SCN is present in the soil and exposed to such active ingredients for a brief amount of time. While there may be a yield benefit from using seed treatments in some instances, it is not always economically practical. Utilize seed treatments to help manage SCN only as a part of a well-rounded integrated pest management program that begins with prevention and utilizes host resistance when available.

**Cover crops and SCN**

There are three potential outcomes of a cover crop species interacting with SCN-

1. Increasing SCN population densities if the cover crop species is a good host for SCN reproduction.
2. No effect on SCN population densities.
3. Decreasing SCN population densities if a cover crop species acts as a trap crop, produces toxic allelochemicals (kills the eggs and nematodes), produces inhibitory allelochemicals (inhibits hatching), or stimulates the hatch of SCN juveniles without providing a suitable host.

However, there are **no conclusive data on the effects of cover crops on SCN**. There are some cover crop cultivars

Table 15.2 Nematode-protectant seed treatments that offer different modes of action.

| Product | Company | Targeted crop | Targeted Nematode | Active ingredient | Mode of Action |
|---|---|---|---|---|---|
| Avicta | Syngenta | soybean, cotton, corn | all plant parasitic nematodes (PPNs) | abamectin | inhibits nematode nerve transmission |
| Clariva | Syngenta | soybean | Soybean cyst nematode (SCN) | *Pasteuria nishizawae* | nematode parasite |
| ILeVO | BASF | soybean, corn | SCN, root knot nematode (RKN), lesion | fluopyram | SDHI enzyme inhibitor |
| Aveo EZ | Valent | soybean, corn | SCN, RKN, lesion, others | *Bacillus amyloliquefaciens* | not specified |
| Saltro | Syngenta | soybean | SCN, RKN, reniform, lance, lesion | Pydiflumetofen | SDHI enzyme inhibitor |
| BioSt Nematicide 100 | Albaugh | soybean, cotton, corn | SCN, RKN, reniform, sting | heat-killed *Burkholderia spp.* strain A396 cells and spent fermentation media | not specified |
| Trunemco | Nufarm | soybean, cotton, corn | all PPNs | *Bacillus amyloliquefaciens,* strain MBI 600 | protective colonization |
| VOTiVO | BASF | soybean, cotton, corn | all PPNs | *Bacillus firmus* | living barrier of protection on roots |
| Nemasect | Beck's | soybean, corn | all PPNs | heat-killed *Burkholderia rinojenses* + fermentation media | not specified |

or mixes marketed for their ability to "suppress SCN" or "reduce SCN" or even "eradicate SCN." However, there are no data to support these claims. If planning to grow cover crops, do so for the known agronomic benefits and not for SCN management.

### Root-Knot Nematodes

Root-knot nematodes (RKN) are currently a problem for some soybean producers in southern Illinois, and certain soybean-parasitic root-knot nematodes have been found as far north as Quincy. Life cycle and ability to suppress soybean yield are similar to that of SCN in that these nematodes are endoparasites that feed on giant cells within soybean roots. In addition, RKN cause visible knotty-looking galls on soybean roots (hence, the name "root-knot"; Figure 15.6).

Management of RKN requires identifying the nematode species, because several species can damage soybean. Collect soil samples as described in "How to Sample for Nematodes" (p. 205). Please contact the Plant Clinic before submitting a nematode sample for species identification (1102 S. Goodwin Ave., Urbana IL 61801, go.illinois.edu/plantclinic). There are RKN-resistant varieties are available for southern Illinois.

### Other Nematodes

**Lesion nematode.** After SCN, lesion nematode is probably the most common soybean-pathogenic nematode throughout Illinois. Diagnosis of a lesion nematode problem is very difficult because these nematodes cause no specific aboveground symptoms—only stunting and chlorosis, as other nematodes do—and no identifiable root symptoms. Several species of this nematode can be found across the state. Lesion nematodes are small (300 to 750 µm), migratory endoparasites; unlike SCN and RKN, they retain a wormlike shape throughout their lives. Lesion nematodes devastate roots by migrating through them and feeding on root cells. The damage they cause looks very similar to the damage caused by several root-rotting fungi (Figure 15.19). These fungi may infect roots at the same time as lesion nematode, complicating diagnosis.

Fig. 15.19. Corn roots infected (left) and noninfected (right) with lesion nematodes. (image: Illinois Agronomy Handbook, 2009 Edition)

Fig. 15.20. Soybean roots with symptoms of sting nematode damage. (Photo courtesy of the Society of Nematologists.)

As with RKN, management requires identification of the species. Collect soil samples as described in "How to Sample for Nematodes" (pg. 3). Please contact the Plant Clinic before submitting a nematode sample for species identification (1102 S. Goodwin Ave., Urbana IL 61801, go.illinois.edu/plantclinic). No lesion-resistant soybean varieties are available at present, and rotation recommendations depend on the species present.

**Sting, stunt, and pin nematodes.** These nematodes are only mentioned here because some laboratories routinely assay soil samples for them. Stunt and pin nematodes are very common in Illinois soybean fields but are rarely present at population densities high enough to damage soybean. Sting nematodes can be found occasionally in soils with a very high sand content, and the damage looks like severe root rot (Figure 15.20). All three of these nematodes are ectoparasitic, but they can cause problems. The only way to diagnose a sting, stunt, or pin nematode problem is through analysis of a soil sample. Collect samples as described in "How to Sample for Nematodes" (pg. 3) and submit them for analysis to the University of Illinois Plant Clinic (1102 S. Goodwin Ave., Urbana IL 61801, go.illinois.edu/plantclinic).

**Corn-Parasitic Nematodes**

Nematodes are the most frequently overlooked cause of corn disease, even though they probably cause at least $80 million in corn yield losses each year. Just as with soybean, these tiny animals cause aboveground symptoms that could be attributed to other types of stress (for example, stunting or chlorosis), and they can intensify expression of specific symptoms due to nutrient deficiency, herbicide injury, and other causes. It is generally thought that nematodes are not important in corn production— that the injury they cause is insignificant, confined to sandy soils, and not worth the effort it takes to find the damage and identify the nematodes—but this conventional wisdom is wrong. Nematode injury to corn is not rare; it is simply difficult to diagnose. It is human nature to discount problems that are hard to see and complicated to recognize. Don't let nematodes be the last thing on your list of problems to look for in corn production.

Adding to the difficulty of diagnosis is the probability that few corn nematode species cause direct injury on their own. They interact with other problems to intensify symptoms. They also occur in polyspecific communities (that is, in combination with several other plant-pathogenic nematode species), and corn nematologists believe that corn injury due to nematodes is not frequently a one-nematode-one-disease situation. The practical implication of corn injury as an "interaction disease" is that it requires highly trained people to diagnose and supply management recommendations. There is no easy fix for the difficulty of diagnosing corn nematode problems.

Lance, needle, lesion, and dagger nematodes are the nematodes responsible for most of the suppression of corn yields in Illinois. Lance and lesion nematodes are endoparasitic (Figure 15.4) on corn, whereas needle and dagger nematodes are ectoparasitic (Figure 15.3). Management recommendations depend on species identification by a qualified laboratory. Collect soil samples as described in "How to Sample for Nematodes" (pg. 3). Please contact the Plant Clinic before submitting a nematode sample for species identification (1102 S. Goodwin Ave., Urbana IL 61801, go.illinois.edu/plantclinic).

**Lance and Lesion Nematodes**

Of the four species of lance nematode that can parasitize corn, *Hoplolaimus galeatus* is the one that affects corn yields in Illinois. Lance nematode is large for a nematode (around 1 mm or more in length) and it is not unusual to find this nematode in silt loam soils. Lance nematodes are extremely common, with a very wide host range, including monocots and dicots. As few as 100 lance nematodes per 100 $cm^3$ of soil will damage young corn plants. Like lesion nematodes (described in the next paragraph), lance nematodes are endoparasites on corn (Figure 15.21). Plants that appear to grow out of early damage will yield significantly less than plants that appear healthy in the same field.

Lesion nematodes are probably the most economically important of the corn-pathogenic nematodes. At least 15 species parasitize corn; three—*P. brachyurus*, *P. hexincisus*, and *P. zeae*—are well-documented corn pathogens. Eight species are known or potential pathogens of corn in Illinois. The damage that lesion nematodes cause on corn is very similar to that described for soybean in the previous section. Resistance to lesion nematodes has been investigated very little, but it is known that some hybrids are less suitable hosts than others.

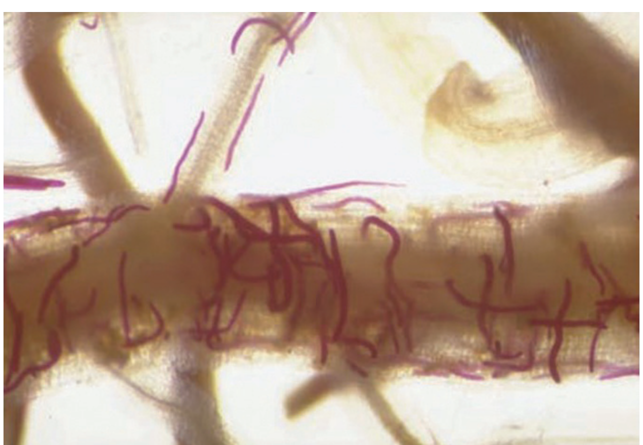

Fig. 15.21. Corn roots infected with lance nematodes (stained pink; Photo courtesy of G. Tylka).

Control of lance and lesion nematodes, in the absence of suitable chemical controls, depends on species identification. Where polyspecific communities occur, rotation crop recommendations must be based on knowledge of host preference. Sanitation and natural-product-based soil amendments have provided lesion nematode control in some cases.

**Needle and Dagger Nematodes**

Needle and dagger nematodes are very large nematodes. Both are ectoparasites, remaining outside the roots while they use their long stylets to feed on cells deep within (Figure 15.3). Needle nematodes are limited to soils with a very high sand content, whereas dagger nematodes may be found in heavier soils.

**Dagger nematodes.** The dagger nematode can be up to 2 mm long, but it is less sensitive to sand content than the needle nematode. Very little is known about the dagger nematode–corn relationship. Suppression may be possible with tillage because this nematode is highly sensitive to soil disturbance. Its long life cycle (perhaps a year) and its occurrence in the upper layers of the soil profile make it vulnerable to tillage operations.

**Needle nematodes.** Needle nematodes can cause spectacular losses—up to 62%—in infested fields (Figure 15.2). High rainfall and cool spring temperatures encourage needle nematode activity and the appearance of needle nematode damage. These nematodes feed on root tips, stunting the lateral roots and essentially destroying the fibrous root system (Figure 15.22). The root damage looks very similar to herbicide injury. Heavily parasitized seedlings may be killed. Infected corn plants can appear to grow out of early damage, but yield will be significantly reduced. Older infected plants appear to be under severe drought stress.

Table 15.2. Generalized population thresholds for risk of damage by plant-parasitic nematodes in Illinois.[a]

| Nematode common and generic names | Notes | Threshold numbers per 100 cubic cm of soil for degrees of severityb | | | | |
|---|---|---|---|---|---|---|
| | | Not significant[c] | Minor[d] | Moderate[e] | Severe[f] | Very severe[g] |
| Cyst (Heterodera) | cysts, soybeans only | - | - | 1-5 | 6-25 | >25 |
| Cyst (Heterodera) | eggs, soybeans only | 1-50 | 51-100 | 500-3,000 | 3,000-6,000 | >6,000 |
| Dagger (Xiphinema) | | 1-10 | 11-25 | 26-50 | 51-100 | >100 |
| Lance (Hoplolaimus) | | 1-10 | 11-40 | 41-75 | 76-150 | >150 |
| Lesion (Pratylenchus) | preplant only | 1-10 | 11-25 | 26-50 | 51-100 | >100 |
| Needle (Longidorus) | corn only | - | 1-5 | 6-20 | 21-75 | >75 |
| Pin (Paratylenchus) | | 1-50 | 51-100 | 101-500 | 501-1,000 | >1,000 |
| Ring (Criconemoides) | | 1-75 | 76-150 | 151-300 | 301-500 | >500 |
| Root-knot (Meloidogyne) | juveniles | 1-10 | 11-40 | 41-80 | 81-150 | >150 |
| Spiral (Helicotylenchus) | | 1-75 | 76-150 | 151-300 | 301-500 | >500 |
| Sting (Belonolaimus) | | - | 1-5 | 6-20 | 21-50 | >50 |
| Stubby-root (Paratrichodorus) | | 1-5 | 6-20 | 21-50 | 51-100 | >100 |

Table compiled by D.I. Edwards (2003) and T.L. Niblack (2005).

[a]Figures are guidelines only; thresholds often must be increased or decreased substantially, depending on plant weather conditions, sampling and extraction methods, and other biotic and abiotic factors.

[b]Based on soil analysis unless otherwise indicated; figures in the columns underneath (left to right) subjectively correspond to trace, low, moderate, heavy, and very heavy nematode population levels.

[c]Population of no consequence during present growing season; potential for increase to damaging level remote in subsequent years.

[d]Population of little consequence at present; potential for increase to damaging level remote during present growing season but good on highly susceptible, monocultured hosts in subsequent years.

[e]Borderline situation with soil nematodes; measurable damage from nematodes alone highly dependent on present and future weather conditions and fertility level; nematodes possibly a contributing factor in a disease complex with fungi, bacteria, viruses, and/or other nematodes; control measures may not be economically practical; strip test recommended; continued monocultured may result a in severe problem. Eventual mortality of parts or all of plant can be expected with foliar and stem nematodes; treatment or destruction of plant recommended.

[f]Population sufficiently high to cause severe economic damage and some plant mortality; established planting may not be salvageable; control measure mandatory.

[g]Population sufficiently high to cause severe economic damage and some plant mortality; established planting may not be salvageable; control mandatory.

Fig. 15.22. Corn roots with severe (top) and slight (bottom) damage due to needle nematodes (Photo courtesy of T. Jackson).

Two factors make needle nematode damage relatively easy to diagnose. First, their size (4 to 5 mm long) makes the nematodes relatively easy to see in a corn soil sample (although a microscope is still required). Second, their occurrence only in sandy soils means they do not have to be considered as the cause of problems in heavier soils.

In Illinois, very good threshold numbers have been established for needle nematode damage. One to five needle nematodes per 100 cubic centimeters of soil can cause a moderate level of damage, whereas more than 25 can cause very severe damage. Corn planting should be avoided in fields with high numbers of needle nematodes.

Although they are relatively easy to diagnose, needle nematodes are not easy to control without nematicides. Management of needle nematodes requires monocotyledonous weed control because the nematodes have a wide host range and can maintain and even increase their population densities on such weeds. Rotation to a nonhost crop, such as soybean, can reduce needle nematode populations if weed control is good.

**Nematode Damage Thresholds**

Decades of experience and research by nematologists in Illinois have given corn and soybean growers excellent guidelines for determining the risk of damage by nematodes (Table 15.2). As mentioned in the preceding sections, however, interpretation of these numbers depends on the unique situation from which the soil samples were taken. The quality of the information you get from soil samples depends on the quality of the samples!