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Nematodes

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N ematodes are roundworms, similar to the animal parasites encountered in livestock and pets. Soildwelling nematodes are both good guys and bad guys in crop production. The good nematodes, which don't get ______ much press, feed on



Figure 15.1. Bacterial-feeding nematodes. (Photo courtesy of E. Bernard.)

fundin press, reed on fungi, bacteria, and other creatures that live in the soil and thereby recycle the nutrients contained in it (**Figure 15.1**). 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 a bad name. This chapter addresses the most important plantpathogenic nematodes in Illinois agriculture.

How Nematodes Damage Plants

Plant-pathogenic nematodes feed only on plants; in fact, they cannot sustain themselves on anything else. 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 cause yield losses without causing obvious symptoms (**Figure 15.3**), 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 potential 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

Figure 15.2. Cornfield trial in soil heavily infested with root-feeding nematodes. (Photo courtesy of Greg Tylka.)

• 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 15.4), which feed from outside the root, or endoparasites (Figure 15.5), which feed from inside the root.

All plant-feeding nematodes feed by means of a stylet, a structure in the head of a nematode that allows it to pierce plant cell walls (**Figure 15.6**). The stylet



Figure 15.3. SCN-resistant (left) and SCN-susceptible (right) soybean varieties in a field heavily infested with soybean cyst nematode. Yield of the susceptible variety was 30% less than that of the resistant variety.



Figure 15.4. An ectoparasitic nematode (bottom center feeding on a root tip. (Photo courtesy of the Society of Nematologists.)



Figure 15.5. An endoparasitic nematode (stained red) feeding within a soybean root. (Photo courtesy of A. Colgrove.)



Figure 15.6. 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. (Photo courtesy of E. Bernard.)

Figure 15.7. Rootknot nematode-resistant (left) and -susceptible (right) soybean varieties showing the characteristic galling associated with rootknot infection. (Photo courtesy of the Society of Nematologists.)





Figure 15.8. Early-season symptoms of soybean cyst nematode infection (and perhaps other factors) include stunting and yellowing. (Photo courtesy of A. Wrather.)

tip (not visible in the figure), 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 through the stylet, inject secretions, or both.

Although some ectoparasitic nematodes, such as needle nematode, can be devastating to crop plants (**Figure 15.2**), 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.

Scouting for Nematodes

With the single exception of root-knot nematodes, which cause characteristic galling on plant roots (**Figure 15.7**), 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 15.8**) may be caused by any number of 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 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. To do effective soil sampling, you must first decide the purpose of the sampling.

- For research purposes, sampling must be intensive, and each sample must represent a very small plot 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 15.9**) 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.
- 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 plot" area should be representative of the whole field in terms of soil type, topography,

and treatments. The sampling plot 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 15.10** 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 tube that is 1 inch in diameter, or a shovel or trowel (**Figure 15.11**)
- a bucket (Figure 15.11)
- 1-quart-capacity plastic zipper-style bags (Figure 15.12)
- a permanent marker (**Figure 15.12**)
- a small cooler



Figure 15.9. A "hot spot" in a soybean cyst nematodeinfested field, showing symptoms of nematode infection and potassium deficiency.



Figure 15.10. A zigzag sampling pattern for an area that can range in size from I square meter to I0 acres.



Figure 15.11. 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.



Figure 15.12. Tools recommended for soil sampling for soybean cyst nematode: quart-size plastic bags and indelible marker.



Figure 15.13. After all cores are collected for a sample (left), the soil should be mixed gently but thoroughly (right).



Figure 15.14. Soil samples prepared for shipping or transport 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.

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

• Take 20 to 30 subsamples (represented in **Figure 15.10** 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 and break up clods (**Figure 15.13**).
- 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 15.12).
- Place the sample in a cooler and keep it out of heat and sun until it can be sent to a lab for analysis.
- If the sample is to be shipped, pack it in a cardboard box cushioned with newspaper or some other insulating material (**Figure 15.14**). 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; it is known to occur in every county.

SCN remains a problem year after year because, in most infested fields, yield loss occurs without any visible symptoms, such as stunting, chlorosis (yellowing), or "sick-looking" plants (**Figures 15.3, 15.8,** and **15.9**). If soybean yields are not what they should be in any given 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 may contain up to 200 eggs (Figure 15.15). 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 reduction is dependent on the number of eggs in the soil because the eggs hatch into juvenile worms that invade the roots (Figure 15.16).

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 un-



Figure 15.15. A cyst, broken open to expose the eggs and juveniles within. (Photo courtesy of E. Sikora.)



Figure 15.16. Soybean cyst nematode juveniles after hatching: the infective stage.

identified) that cause the injected cells and their neighbors to form a feeding site, a system of giant cells known as a synctium. 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 male; they regain their original worm shape (although they are much larger) and exit the root system. The other



Figure 15.17. Young female soybean cyst nematode on soybean root. (Photo courtesy of G. Tylka.)

half become females (**Figure 15.17**); they are unable to move because of their large lemonlike 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 15.18**).

Females turn yellow and then brown (**Figure 15.19**) as 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. 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. In 2008, more than



Figure 15.18. Soybean cyst nematode females (small white bodies) on the roots of a soybean plant.



Figure 15.19. 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.

700 resistant varieties were available to soybean producers in Illinois. Their levels of resistance are verified and available at www.vipsoybeans.org.

• Rotate resistant varieties. Never grow the same SCN-resistant variety in the same field twice. No variety is completely resistant to SCN, and adaptation to resistance can occur quickly. Avoid this "race 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.

Race shifts. 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 race shift has occurred. What this means is that the nematodes in the field have adapted to resistant cultivars that have been grown in that field, and they may be causing yield loss even though the cultivar is labeled "resistant." In this case, the best way to plan a management strategy is to have an "SCN type" test done by the Nematology Lab at the University of Illinois (Department of Crop Sciences, AW101 Turner Hall, Urbana IL 61801). This test will determine the extent of the shift and help the grower devise a management plan.

There are four SCN types of concern in Illinois. These are identified in a greenhouse bioassay in which the nematodes from a particular field are placed on each of the four sources of resistance available to Illinois soybean producers. (A "source of resistance" refers to the original resistant parent



Figure 15.20. Soybean plants showing symptoms of sudden death syndrome in a field heavily infested with soybean cyst nematode. (Photo courtesy of T. Jackson.)

in a pedigree; sources include four 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.) SCN types are determined by the nematodes' ability to parasitize a source:

- SCN Type 0 cannot parasitize any of the sources of resistance; therefore, any resistant cultivar may be used to manage this type.
- SCN Type 1 can parasitize PI 548402, often referred to as "Peking." A cultivar with the Peking source of resistance should not be used in a field with this SCN type.
- 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 437654 (Hartwig or CystX, for example) should be used for one season.
- SCN Type 4 can parasitize PI 437654. None of this type have been identified in Illinois except in experimental locations, and they should not occur unless PI 437654 has been used repeatedly in the same location. Management of a Type 4 would require closely monitored tactics over time, and consultation with a nematologist would be advantageous.

Disease interactions. SCN infection stresses plants, which can increase a crop's susceptibility to nutrient deficiencies, water stress, and pathogens. Diagnosis of 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. Take care of the SCN problem first to reduce crop stress.

SCN is known to be directly involved in the development of certain soybean diseases. Sudden death syndrome (SDS; **Figure 15.20**) and brown stem rot (BSR) are the most important of these diseases in Illinois. 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. Seed 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.

Root-Knot Nematodes

Root-knot nematodes 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 reduce soybean yield are similar to that of SCN in that these nematodes are endoparasites that feed on giant cells within soybean roots. In addition, root-knot nematodes cause visible knotty-looking galls on soybean roots (hence, the name "root-knot"; **Figure 15.7**).

Management of root-knot nematodes requires identifying the nematode species, because several species can damage soybean. Collect soil samples as described "How to Sample for Nematodes" (p. 205) and submit them for analysis to the Nematology Lab (Department of Crop Sciences, AW101 Turner Hall, University of Illinois, Urbana IL 61801) or the Plant Clinic (plantclinic.cropsci.illinois. edu). Root-knot nematode–resistant varieties are available for southern Illinois.

Other Nematodes

Lesion nematode. After SCN, lesion nematode is probably the most common soybean-pathogenic nematode in 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 μ m), migratory endoparasites; unlike SCN and root-knot nematodes, 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 15.21**). These fungi may infect roots at the same time as lesion nematode, complicating diagnosis.

As with root-knot nematodes, management requires identification of the species. Collect soil samples as described in "How to Sample for Nematodes" (p. 205) and submit them for analysis to the Nematology Lab (Department of Crop Sciences, AW101 Turner Hall, University of Illinois, Urbana IL 61801) or Plant Clinic (plantclinic.cropsci.illinois. edu). 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



Figure 15.21. Corn roots infected (left) and noninfected with lesion nematodes.



Figure 15.22. Soybean roots with symptoms of sting nematode damage. (Photo courtesy of the Society of Nematologists.)

are very common in Illinois soybean fields but rarely 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 15.22**). 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" (p. 205) and submit them for analysis to the Nematology Lab (Department of Crop Sciences, AW101 Turner Hall, University of Illinois, Urbana IL 61801) or Plant Clinic (plantclinic.cropsci.illinois. edu).

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 rare, confined to sandy soils, and not worth the effort it takes to find the damage and diagnose the nematodes—but this conventional wisdom is wrong. Nematode injury to corn is not rare; it is simply difficult to identify. It is human nature to discount problems that are hard to see and hard to diagnose. 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 onenematode–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 15.5) on corn, whereas needle and dagger nematodes are ectoparasitic (Figure 15.4). Management recommendations depend on species identification by a qualified laboratory. Collect soil samples as described in "How to Sample for Nematodes" (p. 205) and submit them for analysis to the Nematology Lab (Department of Crop Sciences, AW101 Turner Hall, University of Illinois, Urbana IL 61801) or Plant Clinic (plantclinic.cropsci.illinois.edu).

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. Although lance nematode is large for a nematode (around 1 mm or more in length), 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 cm³ of soil will damage young corn plants. Like lesion nematodes (described in the next paragraph), lance nematodes are endoparasites on corn (**Figure 15.23**). 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.

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 15.4**). Needle nematodes are limited to soils with a very high sand content, whereas dagger nematodes may be found in heavier soils.

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 15.24). 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.

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 oc-



Figure 15.23. Corn roots infected with lance nematodes (stained pink; photo courtesy of G. Tylka).

currence 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 popu-



Figure 15.24. Corn roots with severe (top) and slight (bottom) damage due to needle nematodes (photo courtesy of T. Jackson).

lation 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 15.1**). 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!

		Threshold numbers per 100 cubic cm of soil for degrees of severity ^b				
Nematode common and generic names	Notes	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	51-500	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	501-1000	>1,000
Ring (Criconemoides)		1–75	76–150	151-300	301-600	>600
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 15.1. Generalized population thresholds for risk of damage by plant-parasitic nematodes in Illinois.^a

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

^aFigures 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.

^bBased 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.

^cPopulation of no consequence during present growing season; potential for increase to damaging level remote in subsequent years.

^dPopulation 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.

^eBorderline 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.

^fPopulation sufficiently high to cause severe economic damage and some plant mortality; established planting may not be salvageable; control measure mandatory.

^gPopulation sufficiently high to cause severe economic damage and some plant mortality; established planting may not be salvageable; control mandatory.