

DIAGNOSIS AND MANAGEMENT OF NEMATODES IN CORN

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Nematodes, also known as roundworms, are a phylum of nonsegmented invertebrates that are the most numerous multicellular animals present in soils and plant tissues. Although their numbers can easily exceed 10 billion per acre of soil, the importance of nematodes is often overlooked due to their small size (most are less than 1/25 inch in length). Many species are beneficial, either because they feed on fungi and bacteria, accounting for a significant amount of nitrogen mineralization in the soil, or as parasites of insect pests. Other species, however, are parasites of plant roots and, in some cases, can severely limit crop production. There are over 60 plant-parasitic species associated with corn in North America (Norton, 1983). The most common nematodes encountered in commercial corn fields in the North Central Region are listed in Table 1. During feeding, these nematodes puncture plant cell walls with a hollow stylet and secrete digestive enzymes into the cell. Injury results from wounding and from toxicity and enzymatic activity of the secretions.

Feeding Habits

Plant-parasitic nematodes are usually categorized according to their feeding behavior. Those species that inhabit the soil throughout their life cycle and only insert their stylets into plant roots are referred to as **ectoparasites**. These nematodes often have elongated stylets and preferentially feed at or near root tips. **Endoparasites** penetrate plant roots and, for most species associated with corn, migrate through the root cortex, feeding and laying eggs. A few species exhibit both or intermediate feeding behaviors. It is important to note that while ectoparasites are always recovered from soil, root sampling is necessary to detect endoparasites during the growing season.

Injury Symptoms

Symptoms of nematode injury to corn primarily consist of reduced plant growth and vigor, with moderately distinctive root abnormalities present for some species. Typical aboveground symptoms, such as stunting, chlorosis, and wilting, result from reduced water and nutrient availability due to disrupted root function. Consequently, these symptoms are commonly attributed to fertility or drought-related stresses. The most characteristic manifestation of a nematode problem in the field often is the irregularity or patchiness of the symptoms. Yield

losses, however, can occur in the absence of conspicuous aboveground symptoms.

Belowground symptoms can be more diagnostic but caution should be exercised. Many of the common symptoms, including swollen or discolored root tips and proliferation of lateral roots are also characteristic of damage due to dinitroaniline herbicide carryover, anhydrous ammonia excesses, and aluminum toxicity. Proper diagnosis of a nematode problem must ultimately rely on a nematode assay to determine the types and numbers of nematodes present.

Sampling for Nematode Assay

There are two important reasons for nematode sampling in commercial corn fields: (1) diagnosis of a nematode problem and (2) advisory purposes (i.e. as a basis for making management decisions). Separate sampling strategies are required for each category and are detailed below.

General Sampling Guidelines

Cost is usually a limiting factor when submitting samples for nematode assay. For this reason, most suggested sampling procedures begin with the collection of a number of individual soil cores which are bulked, thoroughly mixed, and subsampled for analysis. The more cores included in the bulked sample, the greater the precision of the population estimate for the field. Typically, 10-20 cores are recommended.

Individual cores should be collected with a standard soil probe (if unavailable, a shovel can be used) to a depth of 6 to 8 inches. The final assay sample should consist of at least a pint of soil in a sealed plastic bag, maintained at a cool temperature, and submitted promptly. A detailed description of the site, symptoms, cropping history, and pesticide use should accompany the sample. There are a number of university and private laboratories providing assay services in the North Central Region. Fees vary considerably among laboratories.

Diagnostic Sampling

Diagnostic sampling is particularly important for corn nematodes because yield loss relationships have not been well-documented for a number of species. Once aboveground symptoms of stress occur, proper sampling can provide evidence of nematode damage or can help eliminate nematodes as the cause of a problem. Samples for diagnosis should be collected from the root zone of plants as soon as symptoms appear, typically 6 to 8 weeks after planting. **Separate samples should be submitted from both affected areas and nearby unaffected areas.** It is also useful to collect samples from plants showing moderate, as well as severe, symptoms.

Several intact root systems should be included with any sample collected during the early growing season.

Advisory Sampling

For those nematodes with established yield loss relationships, sampling is a crucial component in the management decision process. The extent of crop damage generally depends on the number of nematodes present at the time of planting. In some cases, an estimate of field population levels can provide a fairly accurate prediction of yield loss severity. Advisory samples usually are collected prior to planting but samples from the previous season, when nematode densities tend to be at their highest levels, can also be useful (this requires some knowledge of nematode survival rates). **It is a good practice to periodically monitor fields and maintain a recorded history of nematode levels, as well as yield performance.** Fields should be divided into areas of uniform soil type and cropping history for sampling, with 10 to 20 soil cores collected in a zig-zag pattern from each area. Most nematologists recommend one composite sample for each 10 to 20 acres but this may not be feasible when the size or number of fields is large. The larger the area sampled, the more soil cores that should be collected for each sample.

Thresholds: Interpreting Assay Results

Most plants will tolerate moderate levels of parasitism by most nematode species without measureable effects on yield and corn is no exception. Rapid growth and development of the corn root system under favorable growing conditions often provides corn plants with an impressive capacity for recovery from early-season injury. The number of nematodes necessary to have a measurable effect (often exhibited as stunting) on a host plant is referred to as the tolerance limit or **damage threshold**. The population density at which yield loss becomes great enough to warrant a management response is considered the **economic threshold**. Nematicide costs are a good basis for determining economic thresholds for corn because they reflect a principal method of control. For instance, use of a nematicide would currently require a predicted yield loss in excess of 7 to 8 bushels per acre to be profitable, assuming direct costs alone. Note that this is only a 5% loss for irrigated corn with a yield potential of 160 bushels per acre but requires a 10% loss for 80 bushel per acre dryland corn.

Threshold levels for corn nematodes currently in use by laboratories in the North Central Region encompass a wide range of values (Table 2). Some important considerations in interpreting nematode assay results include the following:

- (1) **Extraction efficiency.** Extraction techniques vary among

laboratories and recovery efficiencies vary among nematode species and procedures. A given technique may provide good recovery for one nematode but poor recovery for another. Some labs correct for efficiency while others do not.

(2) **Soil volume.** Most laboratories report nematode densities as numbers per volume of soil. A volume of 100 cm³ is common but this may differ among labs. Correction for volume is often necessary when comparing thresholds and assay results from different laboratories.

(3) **Definition of threshold.** Values may represent either the damage or economic threshold. The difference between the two values can be considerable.

(4) **Regional influences.** Threshold values are not absolute. They vary with soil texture and other environmental conditions.

(5) **Species-specific differences.** Nematode species within a single genus can differ in pathogenic potential.

(6) **Polyspecific communities.** Most commercial corn fields contain several species of parasitic nematodes but studies of the effects and interactions of multiple species are extremely rare.

(7) **Time of sampling.** Since nematode populations generally increase during the growing season, densities in excess of threshold levels are more common as the season progresses. Predictive threshold values generally apply only to populations immediately prior to planting.

(8) **Basis for threshold value.** Many threshold values are not supported by hard data and represent little more than guesses based on circumstantial evidence. Furthermore, the economics of management practices often have not been critically evaluated, particularly for marginal situations.

Management Strategies

Nematode management in corn has principally relied on preplant applications of nematicides to reduce early-season population levels below damage thresholds. There is currently no nematode resistance available in commercial hybrids, although the genetic potential for reduced susceptibility has been identified for several pathogenic species (Smolik and Wicks, 1987; Waudt and Norton, 1986). There are few management options, including nematicides, available for an established crop. The most effective corn nematode management strategies integrate all of the following procedures:

Cultural practices. Maintenance of recommended soil fertility and moisture (for irrigated corn) levels will maximize yield potentials and may increase crop tolerance limits. Good weed control is essential because many weeds, especially grasses, are hosts for a number of corn nematode species and can be a significant source of population increase in a field. Cover crops can increase the severity of nematode damage to a

succeeding corn crop for the same reason, and should be chosen carefully. Tillage practices and management of cover crop residues do not appear to have consistent effects on corn nematodes (McSorley and Gallaher, 1994). The agronomic benefits associated with cultural practices, in general, are probably greater than any consequences of their effects on nematode populations.

Crop rotation. Rotation with nonhost crops is one of the most effective practices for managing a variety of pests that have a limited host range. Unfortunately, many corn nematodes are generalist plant feeders with a wide host range. The corn-soybean rotation common in the North Central Region, for example, guarantees a continuous host crop for many nematode species, with the consequences most often reflected in the corn crop. Nonetheless, nonhost crops are an effective option in many cases but their use requires precise knowledge of the host range of the target nematode, usually at the species level.

Nematicides. The efficacy of nematicide treatments is based on reductions in early-season nematode population levels or feeding pressure and the subsequent establishment of a healthy root system. The effect is short-term, however, and nematode population densities typically recover by the end of the season, sometimes to higher levels in treated than nontreated areas as a consequence of better root growth. Other considerations include environmental concerns, which have led to severe restrictions in pesticide availability and use, and the expense of nematicide treatment. In most cases, it is advisable to evaluate the economic benefit of a treatment using test strips before committing to large-scale application. Always limit nematicide use to problem areas (i.e. spot-treat where possible). **The efficacy of a specific compound will vary with nematode species and environmental conditions so check with extension personnel for local nematicide recommendations.**

Guidelines for Nematode Management: Irrigated Corn in Sandy Soils

Ectoparasites

Sting nematodes (*Belonolaimus* spp.). Distribution of sting nematodes is limited, with highest populations found in soils with >90% sand content. These nematodes are parasites of a wide range of crops, including soybean, but rotation to alfalfa has been highly effective for reducing population densities in Kansas (Todd, 1991). Damage potential is high and any number warrants a management response (Todd, 1989). Nematicide treatments have produced significant corn yield increases in field tests.

Needle nematode (*Longidorus breviannulatus*). As for sting nematodes, the distribution of these nematodes is limited, with

highest populations found in soils with >90% sand content. Alfalfa and soybean are nonhosts. Damage potential is high, with numbers as low as 10 per 100 cm³ soil causing observable symptoms (Malek et al., 1980). Nematicide treatments have produced significant corn yield increases in field tests.

Stubby-root nematodes (*Paratrichodorus* spp.). Stubby-root nematodes are fairly common in sandy soils and have a wide host range. Reported as a serious pest in southeastern states, their damage potential has not been well-documented for corn in the North Central Region.

Dagger nematodes (*Xiphinema* spp.). Dagger nematodes have a wide host range and are common in all soil types but the largest populations are encountered in sandy soils. Evidence for injury to corn is largely circumstantial.

Ring nematodes (*Criconebella* spp.). Ring nematodes have a low damage potential. There are no documented examples of economic losses from this nematode in corn. Turfgrasses in Kansas commonly support densities in excess of 1,000 per 100 cm³ soil with little or no aboveground symptoms.

Endoparasites

Lance nematodes (*Hoplolaimus galeatus*). Many legumes and graminaceous plants are hosts for this nematode. Damage potential is moderately high with an economic threshold of approximately 100 nematodes per 100 cm³ soil or 300 nematodes per gram of dry root (Norton and Hines, 1976). Nematicide treatments have produced significant corn yield increases in field tests.

Lesion nematodes (*Pratylenchus scribneri*). Species of *Pratylenchus* are the most common nematodes associated with corn and frequently attain large population densities in roots. Nonetheless, corn appears to be tolerant of large numbers of lesion nematodes, with economic thresholds near 5,000 per gram of dry root (Smolik and Evenson, 1987; Todd and Oakley, 1996). Soil populations are not a good predictor of damage for *Pratylenchus* species, in general. Alfalfa and soybean are nonhosts. Nematicide treatments have produced significant corn yield increases in field tests.

Guidelines for Nematode Management: Dryland Corn in Clay/Loam Soils

Spiral nematodes (*Helicotylenchus* spp.). Both corn and soybeans are listed as hosts for the most common species. Spiral nematodes have low to moderate damage potential. There is no convincing evidence of an economic impact on corn production.

Stunt nematodes (*Tylenchorhynchus* spp.). Stunt nematodes are

common in all soil types but often reach higher densities in heavier soils. There are numerous species and little data to support economic threshold values for any. The economic threshold of *T. annulatus* on sorghum in Kansas is approximately 500 per 100 cm³ soil.

Lesion nematodes (*Pratylenchus hexincisus*). This species is one of the few corn nematodes for which soybean is not a host. Alfalfa is also listed as a nonhost crop. Economic thresholds have been demonstrated to be in the range of 3,000 to 5,000 nematodes per gram of dry root (Norton, 1983; Smolik and Evenson, 1987). Nematicide treatments have produced significant corn yield increases in field tests.

Literature Cited

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Table 1. Nematode occurrence in soil samples from commercial corn fields, KSU Plant Nematology Lab, 1997*.

Nematode	% samples	Mean density/ 100 cm ³ soil**
Lesion (<i>Pratylenchus</i> spp.)	67	86
Stunt (<i>Tylenchorhynchus</i> spp.)	37	128
Dagger (<i>Xiphinema</i> spp.)	30	57
Stubby-root (<i>Paratrichodorus</i> spp.)	19	36
Lance (<i>Hoplolaimus galeatus</i>)	15	87
Ring (<i>Criconemella</i> spp.)	15	20
Sting (<i>Belonolaimus</i> spp.)	7	84
Spiral (<i>Helicotylenchus</i> spp.)	7	75
Needle (<i>Longidorus breviannulatus</i>)	4	15

* 63% of samples contained multiple species.

** Corrected for extraction efficiency.

Table 2. Range of threshold values reported for corn nematodes by public and private laboratories in the North Central Region.

Nematode	Threshold values (range)
Ectoparasites:	Nematodes/100 cm ³ soil
Sting (<i>Belonolaimus</i> spp.)	5 - 50
Needle (<i>Longidorus breviannulatus</i>)	2 - 50
Stubby-root (<i>Paratrichodorus</i> spp.)	25 - 100
Dagger (<i>Xiphinema</i> spp.)	40 - 200
Ring (<i>Criconemella</i> spp.)	50 - 100*
Spiral (<i>Helicotylenchus</i> spp.)	25 - 100*
Stunt (<i>Tylenchorhynchus</i> spp.)	25 - 500
Endoparasites:	Nematodes/g root
Lance (<i>Hoplolaimus galeatus</i>)	100 - 400
Lesion (<i>Pratylenchus</i> spp.)	500 - 5,000

* Not currently considered to be of economic importance in Kansas.