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Timely Soil Sampling — A Nematode's Nemesis

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Heartworms, which can endanger the life of your dog, and the organisms causing trichinosis and elephantiasis are well-known nematodes. Unfortunately, nematodes also affect crops, taking their toll in reduced yields and vigor. In cotton there are three important species of these microscopic worms which invade root cells and cause damage.

REGION	%LOSS	BALES LOST	$LOST MILLIONS
WEST			
Arizona	5.0	89,937	33.7
California	1.4	38,264	14.3
Total		**128,201**	**48.0**
SOUTHWEST			
New Mexico	5.0	4,594	1.7
Oklahoma	0.5	1,088	0.4
Texas	4.0	225,882	84.7
Total		**231,564**	**86.8**
MID-SOUTH			
Arkansas	4.0	37,209	14.0
Louisiana	6.0	95,294	35.7
Mississippi	4.0	82,929	31.1
Missouri	0.5	2,719	1.0
Tennessee	0.2	1,777	0.7
Total		**217,928**	**82.5**
SOUTHEAST			
Alabama	7.5	40,994	15.4
Georgia	5.5	126,437	47.4
North Carolina	trace		
South Carolina	6.0	31,579	11.8
Total		**199,010**	**74.6**
U.S. TOTAL			**$311.0**

Table 1. '95 nematode losses; $ lost estimates assume $0.80/pound. (Source: 1996 BCCP)

In recent years, nematodes have caused increased losses across the Cotton Belt, totaling $311 million in the 1995 season alone (Table 1). In this article, we will describe the biology and distribution of each of these species and offer tips for minimizing nematode damage. Early and timely soil sampling is not only cost effective, it is crucial to controlling nematodes.

What is a Nematode?

Nematodes are worm-like animals which vary greatly in size and feeding habits. More than 10,000 species of nematodes exist throughout the world. Some nematodes are parasites of animals, others feed on plants, some feed on organic matter in the soil, and others feed on nematodes.

Plant-parasitic nematodes, which are usually invisible to the naked eye, require a susceptible plant host on which to feed and complete their life cycle. Some types of nematodes live within root cells, others live outside the roots, and some utilize both habitats. Their stylets, which are hypodermic-like feeding tubes, are used to puncture root cells and extract nutrients from the host.

Symptoms

Severely infected plants may be stunted 50% or more and may wilt under drought stress several days before noninfected plants. Nitrogen deficiency symptoms (general chlorosis and a spindly appearance) often occur. In the case of the reniform nematode, severe potassium deficiency symptoms (i.e. dark green or blue-green leaves, necrotic spots, marginal leaf scorch or die-back of terminal or lateral buds) may occur.

Because most nematodes are not distributed evenly in the soil, symptoms may occur in irregular patches in an affected field (Figure 1). These patches may be small and limited in number, or large and widely distributed. Symptoms are usually most pronounced in the sandiest areas of an infested field.

Figure 1. Cotton affected by reniform nematode. (Photo: W.S. Gazaway)

Below-ground symptoms include swellings and galls on the roots (root-knot nematode, Figure 2), stunted and forked secondary roots and stunted tap roots (lance nematode, Figure 3). The presence of nematodes often increases the severity of seedling diseases and Fusarium wilt. This interaction, combined with the presence of one or more species of nematode, can greatly increase the amount of damage done to yields.

Figure 2. Root galling from root-knot nematode. (Photo: J.D. Mueller)

Impact and Distribution

Yield losses due to nematodes are increasing Beltwide (Figure 4). This alarming increase may be partially a result of improperly diagnosed symptoms formerly attributed to poor soil fertility or unfavorable pH.

Plant-parasitic nematodes are found in every state where cotton is grown (Figure 5). The three species of cotton nematodes are restricted to particular soil types and climatic conditions. Root-knot nematodes affect cotton crops throughout the Cotton Belt. Both the reniform and lance are found in the Southwest, Mid-South and Southeast. Root-knot and Columbia lance nematodes tend to prefer sandy soils. Although the reniform nematode is more often found in silty soils, it also lives in sandy soils and is suspected of displacing the root-knot in such soils.

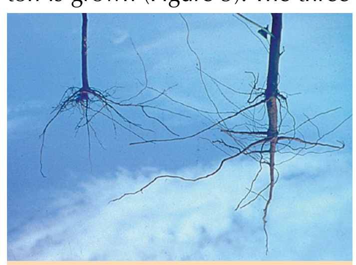

Figure 3. Severe root stunting from lance nematode (left); healthy roots (right). (Photo: J.D. Mueller)

In warmer regions of the Cotton Belt, nematodes are generally more prevalent and reach higher population densities. Populations vary with depth and season. Lowest numbers of nematodes are found at planting and usually climb during the season to attain their highest numbers during mid-to-late summer. Highest populations are generally found in the root zone (6 to 8 inches).

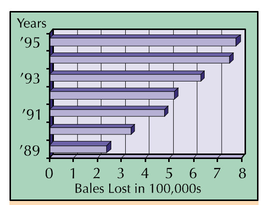

Figure 4. Nematode yield loss estimates. (Source: 1996 BCCP)

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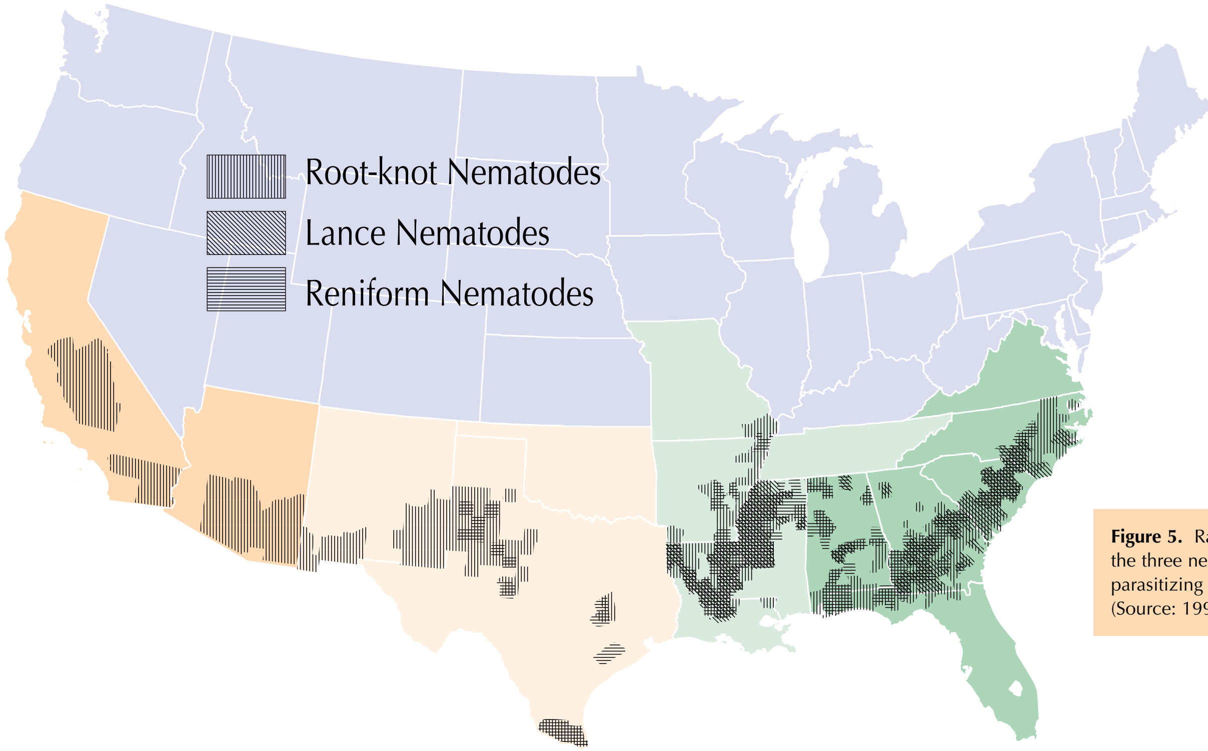

Figure 5. Range of the three nematodes parasitizing cotton. (Source: 1996 BCCP)

Root-knot Nematode (*Meloidogyne spp.*)

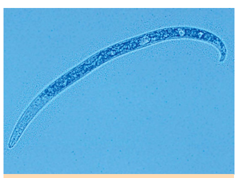

Figure 6. Root-knot nematode larva. (Photo: G.W. Lawrence)

Of the three species of cotton-feeding nematodes, the cotton root-knot (*Meloidogyne incognita*, Figure 6) is the most widespread and causes the most damage throughout the Cotton Belt (Figure 5). More than 75% of cotton fields in some areas are infested. Root-knot nematodes live and feed in the tips of roots. Root cells are transformed by the feeding juveniles into enlarged nurse or “giant” cells which are about ten times larger than normal root cells. These cells block normal development of the root’s vascular system.

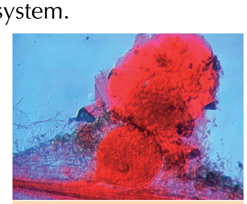

Figure 7. Egg mass and adult female root-knot nematode. (Photo: G.W. Lawrence)

When soils are 80º F, a root-knot nematode’s life cycle can be completed in 4 weeks. Little or no development occurs at soil temperatures under 50º F or over 100º F. The adult female deposits from 300 to 1000 eggs in a gelatinous matrix (Figure 7). As a nematode grows, the surrounding root cells and giant cells enlarge and divide. Multiple infections result in visible and often sizeable galls (Figure 2).

Growth of cotton is stunted from the reduced movement of water and nutrients through the vascular system from the roots to the developing leaves and bolls. Root growth is stunted by the feeding nematodes which consume photosynthate intended for growing roots.

Root-knot nematodes have difficulty surviving in cold or frozen soil. Consequently, their populations decline in the winter when soils freeze and there are fewer living plant roots to nourish them. As many as 99% of the nematodes in a field may die between harvesting one crop and planting the next. Both the relatively short life cycle and great number of eggs laid by adult females combine to produce rapidly increasing populations during the growing season. Population densities can increase more than 100 fold between planting and harvest. Therefore, the best time to sample fields is when the populations reach their peak — just prior to or immediately after crop maturity.

Reniform Nematode (*Rotylenchulus reniformis*)

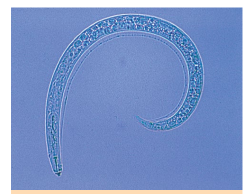

Figure 8. Reniform nematode larva. (Photo: G.W. Lawrence)

Reniform nematodes (Figure 8) rank second to the root-knot nematode in causing damage to cotton in the United States. At its present rate of spread, the reniform nematode will become the most damaging of the cotton nematodes by the turn of the century. Currently its range is from Texas east (Figure 5).

The life cycle of the reniform nematode is completed in 25 to 35 days at temperatures between 77º F and 86º F. An immature female worm penetrates the cotton root. About one-third of the head portion of her body embeds in the vascular tissue while her “tail” end remains outside the root (Figure 9). The back end of her body swells into a reniform (kidney) shape for which the species is named. The female lays 40 to 70 eggs in a gelatinous mass surrounding her back end on the outside of the root.

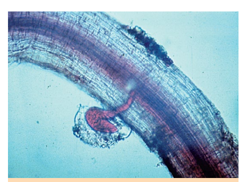

Figure 9. Adult female reniform nematode feeding on root. (Photo: LSU Ag Center)

The adult female, the only stage of the reniform nematode that feeds, stimulates the host cotton to direct its nutrients to the nematode’s feeding site. In penetrating the root’s cortex, the young female kills surface root cells and surrounding tissue. Damaged cells enlarge, lose part of their cell walls, and then fuse to form a multi-celled feeding mass. When large numbers of reniform nematodes attack a plant, much of its ability to take up water and nutrients is impaired — its growth suffers.

Reniform nematodes can increase the incidence of cotton seedling diseases and *Fusarium* wilt. When reniform nematodes feed on seedling roots, plant growth slows or stops. Damaged seedlings are more susceptible to invasion by *Rhizoctonia solani*, *Pythium spp.*, and other fungi causing seedling disease. Plants weakened by seedling disease often die. At best they never develop into vigorous, healthy plants capable of yielding well.

Stunting, yellowing foliage, and reduced yields are common signs of the presence of reniform nematodes in a field. Because the reniform nematode produces many generations per season, populations are extremely high by the season's end. The amount of damage in a field depends on population density. A soil analysis is the only accurate means to detect and identify reniform nematodes.

Lance Nematodes (*Hoplolaimus spp.*)

Of at least eight species of lance nematodes found in the southern United States, only *Hoplolaimus columbus*, *H. galeatus*, and *H. magnistylus* cause significant cotton yield loss. The Columbia lance nematode, *H. columbus*, causes the greatest damage, but has the most limited distribution (Figures 5, 10). A female lance nematode deposits individual eggs, instead of the gelatinous masses typical of the root-knot and reniform nematodes. She lays 20 to 50 eggs at a time, much fewer than produced by the other species.

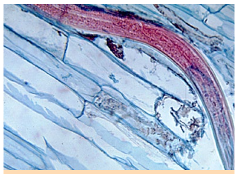

Figure 10. Larva of the lance nematode. (Photo: S.A. Lewis)

Lance nematodes feed on root tips of young cotton plants and alter root growth patterns. Remaining worm-like during their entire life cycle, they feed and migrate through the outer tissues of the cotton root, and to a lesser degree, the inner tissues. A stunted tap root and increased branching of secondary roots in the upper four inches of the soil are typical changes caused by their feeding. The resulting shallow root system limits the uptake of water and nutrients and results in stunted shoots and mildly yellowed leaves.

Clustered or spotty areas of damage in a field are typical of this nematode. Although lance nematodes have not been shown to enhance infection with the *Fusarium* wilt fungus, their migratory feeding behavior creates many wounds on the roots and increases the likelihood of infection by the seedling disease fungus, *Rhizoctonia solani*.

Lance nematode eggs can tolerate dry conditions and cold temperatures. Many survive the winter. Juvenile and adult lance nematodes migrate down into the soil profile as deep as 16 inches. These factors may contribute to the high numbers surviving the winter.

Preventative Measures - the Importance of Soil Sampling

Because nematodes are hidden in the soil and roots, growers need to take an aggressive approach to determine the nematode situation in all fields. A soil sample in time saves twenty nine, or whatever dollar amount you are willing to pay to treat all of your fields for nematodes. By knowing precisely which nematode exists, at what density, and in which fields, a grower can offset the price of soil sample analyses with a cost savings of $21 to $35 for nematicide for each acre left untreated. Conversely, substantial yield losses can be avoided by knowing which fields require action to prevent nematode damage.

When to collect nematode samples. Guidelines may vary from region to region, but in most cases, the best time to sample is late summer or early fall. Nematode populations are easier to detect and estimates are more reliable near harvest time.

How to collect soil samples. Because nematodes are not always uniformly distributed in a field, soil samples must be collected so that they accurately represent the field. Samples should be taken from areas with the same cropping history or soil texture. Areas of fields with different crop histories or soil textures require separate soil samples.

Generally, a sample should represent about 10 acres of one soil type and should consist of between 20 and 30 soil cores. A regular soil probe can be used to sample to a depth of 6 to 12 inches. Cores from a 10-acre section should be mixed thoroughly (a bucket works well for this) and about a quart of this composite sample placed in a plastic bag.

How to handle nematode samples. Nematode soil samples require special care. Handle the sample like a carton of milk — keep it cool, but do not freeze. Do not allow samples to dry out and ship them to the laboratory as soon as possible. Using an overnight delivery service helps ensure their arrival at the laboratory with live, measurable nematodes.

Regional Insights

Across the Cotton Belt, the best way to deal with nematodes varies with the species present, the rotational crops and treatments available, and the environmental factors impacting a particular nematode's distribution. In spite of regional differences, the discussion that follows points out that no matter where you are in the Cotton Belt, diagnosing the presence of nematodes with timely soil sampling is a must in order to design an effective action plan.

West (AZ, CA)

About 20% of the cotton acreage in California's San Joaquin Valley is infested with root-knot nematode. Preplant soil sampling is essential. Successful long-term management of root-knot nematode includes use of nematicides, resistant varieties, and crop rotations. Acala variety NemX has resistance to root-knot nematode and reduces soil populations for subsequent crops. Within the San Joaquin Valley, a number of crops act as non-hosts for cotton root-knot nematode. They include cowpea, resistant processing tomato, and alfalfa. Winter grains and a summer fallow also may be used as rotation crops to reduce root-knot nematode populations. Because weeds (e.g. Bermuda grass, nightshades, and pigweed) allow cotton root-knot nematodes to increase in number, fallow fields must be kept weed free.

The fumigant nematicide, 1,3 dichloropropane, effectively reduces populations of root-knot nematode. Aldicarb protects developing cotton when applied at insecticide rates under the seed at planting. The protection lasts several months, but not for the entire growing season.

Southwest (NM, OK, TX)

Root-knot nematode is the primary nematode problem in West Texas and New Mexico where it can reach high populations, particularly in lighter soils. In the lower Rio Grande Valley and Coastal Bend areas, both reniform and root-knot nematodes are found at low-to-medium population densities. Approximately 18% of the cotton acreage in West Texas has root-knot populations above an economic threshold (high enough to cause significant losses without control measures). About 40% of the cotton acreage in this area is infested, but not all of it above yield-damaging levels. The lower half of New Mexico is infested with root-knot nematodes in about 50% of the counties. One half of those counties have high, economically-damaging populations.

The reniform nematode is a growing threat to cotton production in Texas — particularly because it often escapes notice. Because this nematode does not form readily observable galls like the root-knot, reniform nematodes often are undiagnosed until damaging levels occur. Although growers with heavier soils do not routinely sample for nematodes, the reniform nematode can cause damage in all soil types.

Control is primarily through the use of nonfumigant nematicides in Texas. If nematodes do not build up to high levels, nonfumigant nematicides can do an excellent job reducing losses. Crop rotation is encouraged, but finding an appropriate crop can be challenging. Crops such as corn, sorghum, and most vegetables, are hosts of the cotton root-knot nematode. When irrigated cotton is grown on sandy soils, peanut is one of the best rotation crops. The cotton root-knot nematode does not go to peanut. Wheat is also a poor host. However, if wheat is sown in the fall after cotton, harvested in the spring, and cotton is planted again, nematode numbers will not be reduced. Partial resistance to root-knot nematode can be found in some cotton varieties, but no cotton varieties have resistance to the reniform nematode.

The first step to successful nematode management is to look at roots from mid-July through harvest. If root-knot galls are found, obtain soil samples in the fall so that the level of root-knot infestation can be determined. Sample all fields in which you suspect reniform or root-knot nematodes.

Mid-South (AR, LA, MO, MS, TN)

The southern root-knot and reniform nematodes are of major concern to cotton producers in this region. Reniform nematode has quickly become the most important nematode in several states. Both Louisiana and Mississippi have at least 50% of their acreage infested with reniform nematode. Both of these states have considerable acreage planted on silt loams, an ideal soil for this nematode. Arkansas now has about 10% of its acreage infested with this pest. Although reniform nematode has not yet developed into a major problem in Tennessee or Missouri, it is spreading at an alarming rate throughout this region and within a few years may be present in most of the cotton acreage.

Once the most important nematode pest of cotton in this region, root-knot nematode now ranks second. About 19% of Louisiana's acreage is infested with this nematode. In other states in this region, root-knot nematode is a serious problem usually limited to sandy soils. Galls, evident by July in fields which are severely infested, make identification of this nematode fairly easy.

Both nematicides, as in-furrow applications at planting, and crop rotations are used to manage these nematodes. Corn, sorghum, rice, or a resistant soybean variety can be used successfully to reduce populations of reniform nematode. Root-knot nematode populations drop in rotations with resistant soybean varieties or sorghum. Although some commercial cotton varieties appear more tolerant of nematodes than others, only Stoneville 887 has some resistance to the root-knot nematode.

Soils from problem spots in fields should be sampled from about July until September to determine if nematodes are the culprit. Additional samples should be collected from September until November.

Southeast (AL, FL, GA, NC, SC, VA)

The Southeast is unique in having three major nematode species that affect cotton (Figure 5). Recent soil surveys indicate all three appear to be spreading throughout this region. Columbia lance nematode is a major concern in North Carolina and Georgia. In South Carolina, it is the most important nematode in terms of the percentage of fields infested (over 60%) and total yield losses. More than 37% of infested fields have populations over the damage threshold. The reniform nematode is spreading rapidly in Alabama and Georgia. If the current rate is maintained, the acreage infested with reniform nematode in Alabama will double by the year 2000. Root-knot nematode continues to be a problem in the Southeast. In some fields it may be displaced by reniform nematode, but it is commonly found in the same fields with Columbia lance nematode.

In the Southeast, nematode management comes down to knowing which nematode species is present and at what level. Only fall sampling can provide this information. At a cost of less than $1 per acre, fall nematode sampling is a bargain and a necessity for good nematode management.

Peanut is an excellent rotation crop to use to reduce levels of all three nematode species. However, because of acreage restrictions, it is not an option for many growers. Corn, as a rotation crop, helps reduce reniform nematode levels, but it will not reduce populations of root-knot and Columbia lance nematode. Winter cover crops such as Cahaba white vetch are effective in reducing root-knot populations, but not levels of Columbia lance or reniform nematodes. Most other varieties of vetch are hosts to all three nematode species.

Conclusions

Once a crop has been planted, there is very little that can be done to reduce nematode-induced yield losses. Timely fall sampling is critical to determine if a nematode problem exists in order to design an appropriate nematode management strategy. Proper sampling can result in substantial savings in yield, nematicide product, or both. At a cost less than a dollar per acre, late summer and fall nematode sampling is a bargain hard to pass up for successful nematode management.

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