Plant parasitic nematodes are a serious threat to cotton production in Alabama. Once considered minor pests, nematodes now cost Alabama producers millions of dollars in lost revenues. Nematodes are expected to become an even greater threat in the future with their continued spread into uninfested cotton production areas and with the expansion of cotton acreage in the southern part of the state.

Nematodes spend their entire lives in the soil, feeding on roots of cotton. This and their small size make cotton nematodes and the damage they cause to the roots difficult to recognize in the field by the untrained observer. Aboveground symptoms of nematode-related injury, which include stunting, poor fruit set, and signs of potassium deficiency, are frequently confused with symptoms caused by acid soils, hardpans, nutritional deficiencies, and other diseases. The severity of nematode injury is determined by nematode species, their populations, and prevailing growing conditions.

Nematode injury can be distinguished from a nutritional deficiency and other management-related disorders by its unique distribution patterns in the field. In newly nematode-infested fields, damage occurs in localized, oval areas that run in the direction of the row or tillage pattern. Affected areas may vary in diameter from a few feet to several hundred feet. With time, these areas may expand and coalesce, forming even larger, irregular areas of symptomatic cotton. The entire field may eventually be affected where reniform nematodes are involved.

Nematode injury, with the exception of root-knot nematodes, is difficult to recognize by examining cotton roots. Reniform nematode damaged roots are generally smaller and more sparse, but otherwise roots look healthy. Root-knot nematode damage can be easily identified by the presence of the distinctive swellings or "knots" on cotton roots.

Spread
People are primarily responsible for the spread of nematodes. Spread from field to field occurs usually by means of nematode infested soil particles or clumps clinging to cotton seed, farm equipment, or to the soles of fieldworkers' shoes. After nematodes are introduced to a field, they are spread within the field by cultivation. Once nematodes become established in a cotton field, they remain there forever.

Diagnosing Nematodes In Cotton
A nematode analysis of soil taken from a suspect field is the most effective and most reliable means for establishing the presence of cotton nematodes. Soil samples are collected randomly from the row in the vicinity of cotton's root zone and sent to a nematology laboratory. There, nematodes are separated from the soil, identified, and counted (populations are enumerated). Based on kinds and numbers of nematodes found, the lab recommends corrective actions that are needed.

Kinds Of Cotton Nematodes
Several nematode species are capable of attacking the roots of cotton, but reniform nematodes (Rotylenchulus reniformis) and cotton root-knot nematodes (Meloidogyne incognita) are responsible for 99 percent of the nematode damage in Alabama. Columbia lance nematodes (Hoplolaimus columbus), serious cotton pests in South Carolina and Georgia, are found in a few cotton fields in Autauga County but cause less than 1 percent of production losses attributed to nematodes.

Reniform Nematodes
Reniform nematodes are the most damaging nematode pests on cotton in Alabama. First discovered in an east Alabama cotton field in 1959, reniform nematodes have since spread throughout the major cotton production areas of the state and are now found in 25,000 acres of cotton covering thirteen counties (Figure 1). Yield losses in 1994 were valued

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at approximately $2 million. Until recently, most reniform infestations were found in the southern and central part of the state. However in 1994, serious outbreaks of reniform nematodes were discovered in the Tennessee Valley in North Alabama. In Lawrence and Colbert counties, 41 of 54 suspect cotton fields were found to have damaging levels of reniform nematodes. To date only the Wiregrass area in southeastern Alabama remains free of these devastating nematodes.

Reniform nematodes have several traits that serve them well as plant parasitic nematodes. Their ability to thrive in many types of soil, survive under adverse conditions, produce extremely high populations, and reproduce on a wide variety of crop and weed hosts makes reniform a formidable nematode pest of cotton.

**Symptoms**

Reniform nematode damage is difficult to identify in the field. Infected plants exhibit various degrees of stunting, signs of potassium deficiency, reduced cotton production, and early maturity. Symptoms usually appear in localized areas or “pockets” in newly infested fields (Figure 2). In fields where reniform nematodes have become well established, stunting and other signs of reniform damage are fairly uniform throughout the field.

Cotton roots damaged by reniform nematodes are generally smaller and more sparse than healthy roots, but otherwise they appear normal. A soil nematode analysis is the only means for identifying reniform nematode infestations.

![Figure. 2. Plants severely stunted by reniform nematodes.](image)

**Life Cycle**

Reniform nematodes begin feeding on the roots of young cotton seedlings soon after the seed germinate. The adult female is the only stage that feeds. While still in its worm-like form, the young adult female enters the cotton root and begins feeding. About one-third of the anterior (head) end of her body becomes embedded in the root with her posterior remaining on the outside. In 2 to 3 days after entering the root, her posterior swells to form a reniform (“kidney”) shape. The shape of the adult female gives the reniform nematode its name. The female lays from forty to seventy eggs in a gelatinous mass surrounding her posterior. Adult males coil around the female and the egg mass. In 6 to 7 days later, second stage juveniles emerge from the eggs and then undergo two molts (stages 3 and 4), which last from 8 to 18 days before becoming adults. The reniform nematode completes its life cycle in 21 to 35 days at soil temperatures between 77° and 86°F. It is estimated that reniform nematodes produce up to seven generations in the southern part of the state and as many as five generations in north Alabama.

**Host Range**

Reniform nematodes feed on, reproduce on, and cause injury to a wide variety of plants and crops in Alabama. In addition to cotton, reniform nematodes attack most soybean varieties, tobacco, vegetables, winter legumes, and many weeds (Tables 1 and 2). Reniform nematodes do not feed or reproduce well on many winter cover crops or on corn, grain sorghum, or peanut crops (Table 3). Certain soybean varieties that have resistance to race 3 soybean cyst nematodes are believed to be also poor hosts to reniform nematodes.

**Spread**

Reniform nematodes can be spread by farm equipment, flooding, contaminated cotton seeds, and animals. But, farmers and farm workers are primarily responsible for spread. Farm equipment and vehicles move reniform-contaminated soil from field to field. Reniform nematodes are able to survive long periods in extremely dry soil, and this ensures that large numbers can be successfully transported in this manner.

**Interaction With Other Diseases**

Reniform nematodes increase the incidence of seedling diseases and Fusarium wilt. Reniform nematodes, however, are rarely found in fields where root-knot nematodes are present. The reason for the apparent incompatibility of reniform nematodes with root-knot nematodes is not known.

Table 1. Crops Susceptible To Reniform Nematodes.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Tolerant Of Reniform Nematodes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vetch</td>
<td>Clover</td>
</tr>
<tr>
<td>Cotton</td>
<td>Cowpea</td>
</tr>
<tr>
<td>Soybean*</td>
<td>Tomato</td>
</tr>
<tr>
<td>Tobacco</td>
<td>Okra</td>
</tr>
<tr>
<td>*Soybean varieties with Race 3 resistance to SCN believed to have some resistance to reniform nematode.</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Weeds On Which Reniform Nematodes Feed And Reproduce.

<table>
<thead>
<tr>
<th>Weed</th>
<th>Tolerant Of Reniform Nematodes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crotolaria</td>
<td>Jimsonweed</td>
</tr>
<tr>
<td>Cocklebur</td>
<td>Florida Beggarweed</td>
</tr>
<tr>
<td>Sow Thistle</td>
<td>Florida Pusley</td>
</tr>
</tbody>
</table>

Table 3. Crops Resistant To Or Tolerant Of Reniform Nematodes.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Tolerant Of Reniform Nematodes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peanut</td>
<td>Oats</td>
</tr>
<tr>
<td>Wheat</td>
<td>Barley</td>
</tr>
<tr>
<td>Rye</td>
<td>Grain Sorghum</td>
</tr>
<tr>
<td>Corn</td>
<td></td>
</tr>
</tbody>
</table>

**Cotton Root-Knot Nematodes**

Cotton root-knot nematodes are the most important nematode pest of cotton across the U.S. cotton belt, but root-knot nematodes rank second in importance to reniform nematodes in Alabama. Cotton root-knot nematodes, recognized as a major nematode pest of cotton since the turn of the century, belong to a subgroup (races 3 and 4) of the southern root-knot nematode species (Meloidogyne incognita). It
is the only root-knot species that attacks cotton. Other root-knot species, which include peanut root-knot (M. arenaria), northern root-knot (M. hapla), javanese root-knot (M. javanica), and southern root-knot (races 1 and 2), do not feed or reproduce on cotton. Although cotton root-knot nematodes are found in most soil types, they prefer coarse or sandy soils. Yield losses to root-knot usually range from 10 to 25 percent, but may exceed 50 percent in sandy fields exposed to drought conditions. Damage or yield losses in fields are usually uneven. Some areas of the field may have yield losses up to 100 percent while other areas exhibit no apparent damage. Statewide, cotton root-knot nematodes account for an estimated $1 million in yield losses.

Symptoms

Symptoms of root-knot nematode damage are easily recognized in the field. Infected plants are stunted, often chlorotic, and grouped in clusters that are unevenly distributed in the field. These root-knot infested areas are oval shaped and oblong in the direction of cultivation. Affected areas may be 10 to 30 feet wide and 20 to 50 feet long (Figure 3).

Root-knot nematodes produce distinctive galls on cotton roots that resemble knots in a rope (Figure 4). Galls are more common on secondary roots but can occur on the tap root. Galls on cotton roots are usually smaller and are harder to recognize than those on soybeans and okra and other vegetables.

While the distinctive galls or "knots" on cotton roots are a diagnostic feature that can be used to identify cotton root-knot nematodes, a nematode soil analysis is also useful. Since a nematode soil analysis only identifies root-knot to genera (Meloidogyne spp.), the lab needs information on the field's cropping history to identify root-knot species.

Most damage to cotton results from the physiological changes in the root tissue as root-knot nematodes feed. Giant cells formed during the feeding process disrupt the development of the root's vascular system and impair the root's ability to remove water and nutrients from the soil efficiently. Also, sugars and carbohydrates produced in the leaves are diverted to the nematodes' feeding sites rather than to the developing roots.

Host Range

Cotton root-knot nematodes attack cotton, soybeans, corn, tobacco, and many vegetables. Contrary to popular belief, cotton root-knot nematodes attack and multiply on many commercial field (dent) corn and hybrid crops. Cotton root-knot nematodes also feed and reproduce on winter grass-type cover crops such as wheat, oats, rye, and barley, but root-knot population increases are significantly slowed by cool soil temperatures in the winter. Legume cover crops, including clover and most vetch varieties, are excellent hosts and should not be used in fields where root-knot nematodes are a problem. Weeds susceptible to root-knot attack include bermudagrass, johnsongrass, cocklebur, goosegrass, red root pigweed, purple nutgrass, yellow nutsedge, purple nutsedge, smartweed, teaweed, lamb'squarter, ground cherry, crotalaria, and sicklepod.

Interaction With Other Diseases

Cotton root-knot nematodes increase the incidence and severity of Fusarium wilt and cotton seedling disease. Their role in the Fusarium wilt and root-knot complex is well documented. Although Fusarium wilt is capable of causing wilt in the absence of root-knot, the disease is almost always associated with these nematodes in Alabama.
Columbia Lance Nematode

Several species of lance nematodes can be found in Alabama cotton fields, but only one species, the Columbia lance nematode (Hopla-laimus columbus), seriously damages cotton. Fortunately, Columbia lance nematodes cause little damage to cotton in Alabama because they are found in only a few, scattered fields in Autauga County.

Symptoms

Symptoms appear in localized, scattered areas in the field due to the clustered distribution of the Columbia lance nematode. Like root-knot nematodes, lance nematode infested areas are oval in the direction of cultivation. Infested plants are often stunted and chlorotic. The plant's taproot is severely stunted with numerous secondary roots in the upper 4 inches of the soil (Figure 5).

Life Cycle And Biology

Columbia lance nematodes are migratory ecto-endo-parasites that migrate and feed throughout the outer root tissue. Unlike reniform and root-knot nematodes, lance nematodes retain their worm-like appearance in all developmental stages. All stages feed on cotton roots.

The adult female lays twenty to fifty individual eggs. Although relatively few eggs are produced, a large percentage of offspring survive because they can tolerate severe desiccation and changes in soil condition, and they can migrate vertically in the soil to avoid unfavorable soil conditions. The adult female has a life span from 6 months to a year. It is not known how many times the female lays eggs during her life span.

Host Range

Columbia lance nematodes have a very wide host range. They feed and reproduce on cotton, corn, soybean, wheat, and bermudagrass. Columbia lance nematodes do not feed or reproduce on peanuts, sweet potatoes, tomatoes, peppers, ryegrass, or bahiagrass. Poor hosts for Columbia lance nematode include watermelons, cucumbers, cantaloupes, and okra.

Weeds that are good hosts for Columbia lance nematodes are nut-sedge, pigweed, sicklepod, henbit, crimson clover, and showy crotalaria.

Interaction With Other Diseases

Columbia lance nematodes are known to increase the incidence of seedling diseases caused by Rhizoctonia sp. (soreshin), but they do not affect seedling disease caused by Pythium sp. Lance nematodes are not known to increase Fusarium wilt in cotton.

Nematode Management

Nematode populations can be managed in cotton through the use of crop rotation, resistant varieties, certain cultural practices, and nematicides.

Crop Rotation

Crop rotation is an effective tool for controlling reniform and root-knot nematodes where profitable alternative nonhost crops can be rotated with cotton. Crop rotation is not an effective tool for managing lance nematodes because of their wide host range. In southeast Alabama, peanut is not affected by reniform, root-knot, or lance nematodes, so it is an excellent crop to rotate with cotton.

Grain sorghum is also a poor host for reniform and root-knot nematodes and can be used as a rotation crop in areas where peanut is not available. Corn, a poor host for reniform nematodes, is an effective rotation crop for suppressing it. However, corn should not be used indiscriminately in a cotton rotation system to control root-knot nematodes. Many commercial corn varieties are excellent hosts for root-knot and sustain root-knot populations. Use corn only if the variety is known to have good root-knot resistance. Although soybean is considered a good host for cotton root-knot and reniform nematodes, certain varieties can be used to manage populations of both species. Cotton root-knot nematodes do not reproduce well on soybean varieties that have resistance to southern root-knot nematodes, and soybean varieties that are resistant to soybean cyst nematode race 3 are poor hosts for reniform nematodes.

Fallowing nematode-infested fields is also an effective means of reducing Columbia lance, reniform, and root-knot nematode populations, provided fields are kept clean of weeds. All three nematode species feed and reproduce well on a wide range of weeds, so weed control is essential for fallowing to be effective.

In fields heavily infested with nematodes, a minimum of a 2-year interval with nonhost crops or fallowing is required to bring reniform and root-knot nematode populations down to a manageable level. Crop rotation in nematode infested fields is effective for 1 year. Once cotton has been reintroduced, reniform and root-knot nematodes often will return to their original damaging population levels by the end of the growing season, necessitating a return to nonhost crops or the use of nematicides the following season.

Figure 5. Cotton root showing injury to taproot (left).
Resistant Varieties

No commercial cotton varieties have true resistance to reniform, root-knot, or lance nematodes. Cotton varieties Stoneville LA-887, HS-46, and CB1135 appear to have some tolerance to reniform nematodes, according to a 3-year study conducted in south Alabama.

Some commercial cotton varieties have various degrees of tolerance to cotton root-knot nematodes. Most commercial varieties carry resistance to the Fusarium wilt and nematode complex, but this resistance is primarily for Fusarium wilt—not root-knot. Cotton varieties such as Stoneville LA-887 tolerate root-knot damage much better than others. Some breeding lines carry root-knot resistance in their germplasm. We hope root-knot resistance will be available in future commercial cotton varieties.

Cultural Practices

Certain cultural practices can effectively reduce existing nematode populations and prevent spread of nematodes to “clean” fields. Exclusion or preventing spread of nematodes is particularly important. Once nematodes have been introduced into a cotton field, they can never be eradicated.

To prevent spread of nematodes, cotton growers should assay all of their fields. Nematode-infested fields should be worked last if possible and farm equipment should be washed thoroughly before entering “clean” fields. Used or borrowed farm equipment should be washed or steam cleaned before using.

Nematode populations can be reduced by fall cultivation. Turning the soil and exposing the roots in the fall subject nematodes to the heat and drying action of the sun and deprive them of a suitable place to survive the winter.

Nematicides

Nematicides are currently the most effective tool for controlling reniform nematodes in cotton. Nematicides have been shown to increase cotton yield from 40 to 75 percent in heavily infested fields. Although relatively expensive, nematicides are ideal where rotation is not feasible. Their use allows cotton producers to grow cotton continuously in infested fields without having to rotate with less profitable nonhost crops.

Aldicarb (Temik), and 1,3-dichloropropene (Telone) are two most effective nematicides against reniform. Temik, an at-plant granular nematicide/insecticide, is effective against reniform nematodes at rates from 0.75 to 1.5 active ingredient (a.i.) per acre. Telone II, a pre-plant fumigant, is effective at rates from 3 to 5 gallons per acre. Nematicides are effective for only one growing season, so they must be applied every year.

Nematicides provide nematode protection for the first 4 to 6 weeks, which is sufficient time to allow the plant’s root system to develop. By the end of the growing season, nematode populations in nematicide-treated areas are as high or even higher than those in nontreated areas.
Use pesticides only according to the directions on the label. Follow all directions, precautions, and restrictions that are listed. Do not use pesticides on plants that are not listed on the label.

The pesticide rates in this publication are recommended only if they are registered with the Environmental Protection Agency and the Alabama Department of Agriculture and Industries. If a registration is changed or cancelled, the rate listed here is no longer recommended. Before you apply any pesticide, check with your county Extension agent for the latest information.

Trade names are used only to give specific information. The Alabama Cooperative Extension System does not endorse or guarantee any product and does not recommend one product instead of another that might be similar.

For more information, call your county Extension office. Look in your telephone directory under your county's name to find the number.