# Managing Nematodes in Cotton-Based Cropping Systems

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**The starting point for all nematode management programs is knowledge of the nematode species present in each field and their population levels**. This information can only be obtained by thoroughly sampling each field shortly after harvest and sending the sample to a nematology laboratory for assay. Only then can a grower select the most cost-effective management program for each field and for the farm as a whole.

**Economic Nematode Pests of Cotton**

Root-knot nematode occurs across the entire Cotton Belt. Although they are most commonly associated with damage in sandy soils, they occur across a wide range of soil types. Root-knot nematodes are usually clustered in distribution, with some areas of a field severely damaged while other areas show few or no symptoms. Root-knot nematodes infect cotton roots near the growing points (Fig. 1). They mature inside roots and cause galls to form at the infection sites that are diagnostic and readily visible (Fig. 2).

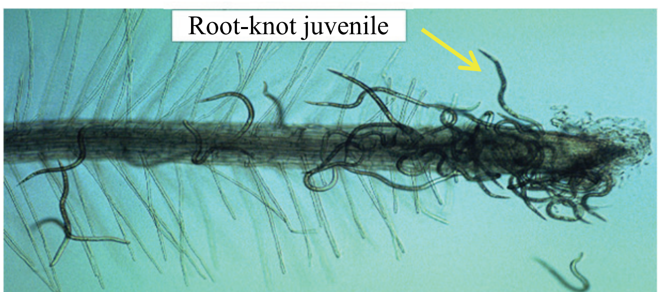


**Figure 1**. Root hairs and $2^{nd}$ stage juveniles of root-knot nematode around the growing point of a cotton root.

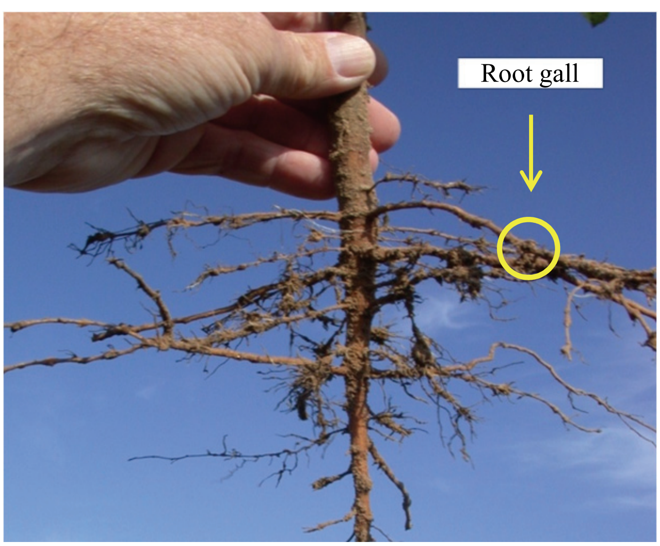


**Figure 2**. Root galling by root-knot nematode.

Reniform nematode occurs in a wide range of soils, but is most common in soils with a higher silt or clay content than those with root-knot nematode. Reniform nematodes are often distributed more uniformly across a field than are other species due to their very high rate of reproduction. Reniform nematode does not cause galls on cotton roots, so diagnosis in the field is difficult. Where infection is severe, female reniform nematodes that are attached to the cotton roots may be seen with a hand lens or dissecting microscope (Fig. 3).


**Figure 3.** Reniform egg masses on a cotton root visible by dissecting microscope.

Columbia lance nematode prefers even sandier soils than does root-knot and occurs primarily in Coastal Plains soils of the southeastern and southern U.S. that contain more than 80% coarse sand. As with root-knot, within-field distribution of Columbia lance nematodes can be strongly associated with sandy areas, and pockets of Columbia lance nematode are common within a field. Symptoms of Columbia lance nematode infection include root systems that are smaller than normal, but no galls are formed. Accurate diagnosis of this nematode requires soil assay by a nematology laboratory.

Sting nematode is also restricted to very sandy areas, and is rarely found where the soil is less than 85% sand content. Sting can be found in most southeastern states, but is restricted primarily to old river bottoms or other very sandy areas. Although sting nematode can be extremely damaging to cotton, it is generally restricted to small areas of a field.

**Table 1**. Damage thresholds per 100 cm$^3$ soil (number of nematodes required to cause a 10% or greater yield loss) as affected by sampling date, soil type, and tillage.

| Nematode Species | October<br>Sand to Sandy loam | January<br>Sand to Sandy loam | October<br>Clay loam | January<br>Clay loam | Pre-plant<br>(turned or disked) |
|---|---|---|---|---|---|
| Southern root-knot | 100 | 50 | 130 | 75 | 40 |
| Reniform | 250 | 150 | 500 | 400 | 50 |
| Columbia lance | 75 | 50 | 175 | 100 | 34 |
| Sting | 5 | 1 | 10 | 1 | 1 |

**Distribution of Nematodes within Fields**

Plant-parasitic nematodes are almost never uniformly distributed within cotton fields. Rather, they will most likely be concentrated where the roots of the crop were most concentrated. Since most cotton roots are in the top 10-12 inches of soil within and near the planted row, nematodes will be most concentrated in this area. Although root-knot and Columbia lance nematodes prefer sandy soils, a common misconception is that these nematodes only occur in the sandy areas of fields. In fact, nematodes may occur anywhere in a field, but damage is most severe (and most evident) in the sandier areas. These areas are already under moisture and nutrient stress and nematode damage to the roots can amplify this damage.

**Sampling for Nematodes**

Developing an effective nematode management strategy for an individual field or for an entire farm requires a knowledge of the species that are present and the population density of each species in each field. Comparing the species density or densities for multiple species to published threshold levels will help to determine if management should be initiated (Table 1). Although they are not absolute and damage from the nematodes may vary according to many factors, threshold values provide an estimate of the risk associated with nematodes in that particular field. Since nematode samples are routinely taken after harvest, damage thresholds are predictive for the next year's crop.

A good sample should consist of 1-2 pints of soil that is a composite of multiple (about 20) individual soil cores from the site to be sampled. Soil should be sampled in the plant row, among stalks where roots are most abundant. Samples should be taken 8-10 inches deep and consist of both soil and small roots that were cut from the root system during the sampling process. The optimum soil moisture for sampling is when soil is moist enough for seed to germinate if they were planted. Do not sample if the soil is too wet or too dry. The samples should be placed in a plastic bag immediately after they are collected to keep the soil from drying out and killing the nematodes. The plastic bag containing the sample should be kept out of the direct sunlight in a relatively cool spot. Placing the samples into an insulated cooler (without ice) is an excellent way to protect the samples from sunlight and from rapid changes in temperature. Do not place ice directly into the coolers with the samples, and do not refrigerate samples prior to shipment to the laboratory. Samples should be held at room temperature inside insulated coolers and shipped to the assay laboratory relatively quickly, preferably on a Monday or Tuesday so they do not spend a hot weekend in the back of a delivery truck or warehouse. Samples more than a week old that have not been stored properly should be discarded.

Nematode samples fall into two general categories:

Diagnostic samples are taken during the season in response to visible plant or crop issues to determine if observed damage is due to nematodes or something else. When plant symptoms are first observed, nematode populations may be fairly low, so it is best to take two samples; one from an obviously affected area and a second from an area on the fringe of the site where plants are expressing symptoms. Nematode counts are often higher at the margin since the plant roots there are in better shape and can support higher nematode numbers.

Predictive samples are used to estimate the risk of a nematode problem in the subsequent crop. They should be taken in a random pattern across the field with at least one soil core per acre. It is best to limit the size of each area sampled to 20 acres. Large fields should be broken down into smaller areas based on differences in soil texture, drainage or crop history.

**Thresholds**

The yield loss that nematodes will cause can be predicted if soil samples are taken in the fall. The density of each nematode species, expressed per 100 ml of soil can be compared to known thresholds (Table 1). Thresholds vary by the combination of host and nematode species. It takes 250 reniform nematodes per 100 ml soil to cause a 10% yield loss on cotton; whereas it takes only 75 Columbia lance nematodes per 100 ml soil to cause the same yield loss. The higher the nematode density, the greater the yield loss will be. Nematode populations normally peak near crop harvest. Therefore, thresholds vary by sample dates. As soil temperatures drop in the fall and no live plant tissue is present, nematode numbers drop due to vertical migration and winter mortality. Thresholds also vary by soil type. The greatest damage from nematodes is observed where high numbers of nematodes are present in sandy soils. Sandy soils do not retain moisture and nutrients, especially in the upper levels of the soil profile. Nematodes typically feed on the growing points of roots, which may result in severely stunted tap roots. Yield losses are typically the result of damaged root systems being unable to take up the needed water and nutrients.

**Table 2.** Hosts versus non-hosts of the primary nematodes that affect cotton

| Nematode Species | Corn | Cotton | Grain Sorghum | Peanut | Soybean* |
|---|---|---|---|---|---|
| Southern root-knot | Host | Host | Host | Non-host | Host |
| Reniform | Non-host | Host | Non-host | Non-host | Host |
| Columbia lance | Host | Host | Host | Non-host | Host |
| Sting | Host | Host | Host | Host | Host |

*Soybean cultivars are available that are root-knot and reniform nematode resistant.

**Nematode Management**

Crop Rotation

Crop rotation is a cost effective means of managing nematodes if the alternative crops fit your farming system. Corn, peanut and soybean are the crops most commonly grown in rotation with cotton; grain sorghum, rice and tobacco are also grown in rotation with cotton in some areas. Root-knot, reniform, and Columbia lance nematodes differ in their abilities to infect and damage these crops (Table 2). All four nematodes can reproduce on soybean as well as cotton. Root-knot and reniform nematode-resistant soybean cultivars are available and may sustain little damage from these nematode species. There are no Columbia lance nematode-resistant soybean cultivars. Root-knot and Columbia lance nematodes can also build up on and damage corn, but corn is not a host for the reniform nematode. None of the three will infect or damage peanut. Grain sorghum is a rather poor host for root-knot nematodes. Most hybrids are partially resistant and do not sustain yield losses or support increases in population levels. Grain sorghum is not a host for reniform nematodes but may be damaged by Columbia lance nematodes.

Growing peanuts in a field will normally reduce the levels of reniform, Southern root-knot, and Columbia lance nematodes. A cotton-peanut rotation is also good for managing the peanut root-knot nematode, the major nematode pest on peanut, because this species does not infect or reproduce on cotton. Among the crops with only minor acreage grown in rotation with cotton, rice is not a host for root-knot, reniform, or Columbia lance nematodes. Root-knot nematode can be an important problem on tobacco; however, reniform and Columbia lance nematodes are not problems on tobacco.

Cultural practices

In addition to crop rotation, any cultural practice which reduces nematode densities or lowers the amount of stress to which a cotton crop is exposed is beneficial. In many Coastal Plains soils, deep tillage (often called subsoiling) is commonly practiced to allow adequate tap root growth. By itself, deep tillage can increase yields 25-50% where shallow hardpans are present. Other forms of deep tillage such as conventional tillage systems that include a turn plow may bury nematodes (as well as weed seeds) deeper in the soil allowing the tap root to grow longer before nematodes can reach and infect the root tips. Since nematodes are most abundant where the root system is located, mixing soil that has been close to plant roots with soil that originated outside the root zone by plowing and cultivation will lower the initial density of nematodes coming into contact with the seed at planting. Disking helps spread soil and can reduce nematode densities by as much as 66% in the top 8 inches. Reduced tillage or strip tillage can have the opposite effect and can have detrimental effects on a nematode management program. Continually cropping in the identical furrow year after year does not disturb the soil profile or dilute the nematodes by redistributing them over a wider area. Encouraging the new roots to grow in the same place as the roots of previous crops have grown, focuses the roots of the new crop in areas where the nematode concentrations are highest. Fields which are strip tilled, especially if they are repeatedly cropped to cotton, should be monitored through an annual soil sampling plan for changes in nematode population levels.

Host plant resistance

Host plant resistance is one of the most effective ways to limit yield losses due to nematodes and can provide control across an entire field for a relatively low price. However, crop cultivars with resistance to all three nematode species that are important in cotton are rare. All currently available nematode-resistant cotton cultivars are effective only against the root-knot nematode. The commercial cotton cultivars that exhibit moderate resistance to root-knot nematode are PHY 367 WRF, ST 5458B2RF, ST 4288B2RF and DP 174 RF. While the level of resistance they exhibit is not effective against high levels of nematodes, they are useful where population densities are less severe. In most cases, these cultivars respond positively to the additional application of a nematicide. There are no commercially available cultivars with resistance to reniform or Columbia lance nematodes.

Fallow Fields and Weed Hosts of Nematodes

An effective strategy for reducing nematode population density in a site is to remove all host plants for the entire growing season, a practice known as fallowing. A truly fallow field can reduce nematode populations by 50-90%. However, if weeds that are hosts for a nematode species are allowed to grow, the beneficial effects of fallowing the field will be minimized. Many of the most common weeds of cotton are hosts for root-knot, Columbia lance, and/or reniform nematodes. Unfortunately in most cases, the weeds suffer very little damage from nematode infections, but may increase nematode population densities. Some common weed hosts include:

Root-knot nematode: nutsedges, certain pigweed species, horseweed, teaweed, certain morningglory species, tall ironweed, black nightshade, and common Bermudagrass.

Reniform nematode: sicklepod, Carolina geranium, morningglories, pigweeds, and purslance.

Columbia lance nematode: morningglories and pigweeds.

Sting nematode: nutsedges and ragweed.

**Nematicides**

A lack of resistant varieties and the desire to mono-crop cotton, or to grow cotton in rotation with corn or soybean may cause a reliance on nematicides for nematode management in cotton. Although they vary in mode of action, application technology and cost, nematicides offer the grower an option to control all of the commonly occurring species of nematodes across a wide range of population densities and environmental conditions (Table 3). The most commonly used nematicide in cotton in the U.S. Cotton Belt has been aldicarb, sold as **Temik®** 15G, which is also highly effective for thrips control. Applying relatively low rates of Temik 15G, 3.5 to 6.0 lbs./acre, was a cost-effective way of controlling both nematodes and thrips. Commencing in 2011, Temik 15G is being voluntarily phased out by Bayer CropScience. MEY Corporation is developing a formulation of aldicarb, **Meymik®** 15G, that has been approved by the EPA for sale in the U.S. **Telone® II** provides control of all nematode species on cotton. A fumigant, it must be applied 7-10 days prior to planting in all states but Georgia, which has a label for at-plant applications on cotton. The 3 gallon/acre rate of Telone II provides excellent control of all nematode species in cotton. Although it has been more than twice as expensive on a per acre basis as is Temik 15G, its ability to control even high population levels of root-knot or reniform nematodes provide it with a niche where it is cost effective. When soil sampling indicates that high levels of nematodes are present, two other fumigant nematicides**, K-pam®** and **Vapam**,® are also labeled for use in cotton for nematode control. Their costs are approximately the same as Telone II but they require a minimum of 14 days between application and planting to avoid possible phytotoxicity. Other nematicides include the seed-applied products **AVICTA®** Complete Cotton from Syngenta, **Aeris®** Seed Applied Treatment from Bayer CropScience and **Poncho®/Votivo®** from Bayer CropScience. The nematicidal component of Avicta Complete Cotton is abamectin. Abamectin has been recognized as a nematicide for over 20 years but could not be used as a soil applied product because it is bound too tightly to soil particles to be effective. Recent advances in seed application technologies allow the application of low rates of abamectin that are not phytotoxic but are high enough to provide some level of nematode control. The nematicide in Aeris is thiodicarb which is also an insecticide and has been sold for years as **Larvin®**. The nematicide in Poncho/Votivo is a bacterium, *Bacillus firmus*. Although these seed treatments offer some control of the three important nematode species of cotton, seed treatment nematicides are suitable only for the control of lower population levels of the nematodes. Seed treatments are very convenient to use. Low populations of nematodes can be controlled by the seed treatment products. Many producers also combine the use of a nematicidal seed treatment with foliar applications of **Vydate® C-LV**. Oxamyl, the active ingredient in Vydate C-LV is transported from leaf tissue to the root system, and has been shown to provide some nematode population and feeding suppression.

**Table 3**. Thresholds* for specific nematicide treatments

| Nematode Species | Low Threshold | High Threshold |
|---|---|---|
| Southern root-knot | 100 | 250 |
| Reniform | 250 | 625 |
| Columbia lance | 75 | 175 |
| Sting | 10 | 25 |
| | | |
| Recommended Nematicide | Aldicarb or Seed treatments ± Vydate | Telone II or K-Pam, Vapam |

*Per 100 cc

**Summary**

Developing a program for each individual farm that will provide the desired levels of nematode control in each field begins with sampling fields and submitting nematode samples to a nematology laboratory for assay. This fundamental knowledge, in turn, allows producers to develop a management plan. Producers should always follow these guidelines.

1. Rotate susceptible with non-host crops whenever consistent with anticipated returns.
2. Sample fields and zones following harvest to assess nematode numbers before the next crop.
3. Avoid planting susceptible crops and cultivars in the same physical rows in consecutive years. If not practical to move rows, subsoil down the row every 2-3 years to improve conditions for root development.
4. Plant nematode-resistant cultivars when available and adapted to your environment and management.
5. Apply nematicides at rates that are appropriate for your nematode populations and soils.

The key to preventing yield loss in cotton is to preserve the integrity and function of the root system, particularly the tap root by preventing stunting from nematode feeding. Protecting cotton roots requires reducing initial nematode numbers to the lowest level possible by whatever method or combination of methods are most appropriate for that particular field and production system.

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