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Management of Economically Important Nematodes of Arkansas Cotton

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Plant-parasitic nematodes are microscopic roundworms that feed on plant roots. There are many types of plant-parasitic nematodes, and some of them can cause severe damage to Arkansas cotton. Nematode feeding injures the root system and can impact yield, sometimes drastically. In addition to direct damage, nematode feeding may allow pathogenic fungi and bacteria to invade roots, resulting in secondary root rots or vascular wilts. Nematode injury can limit the uptake and transport of water and essential nutrients within the plant and result in mild to severe stunting, yellowing of foliage or wilting during the heat of the day. Nematode management is needed when population densities in the soil are high and crop loss reaches economic levels.

Sampling for Nematodes

Soil sampling is the main way (and sometimes the only way) to know if nematodes are present in a field. Sample assays by a nematology laboratory will tell both the type or types of nematodes that are present and the level of infestation (population density) that exists. Because symptoms of nematode damage in cotton may be confused with other problems like nutrient deficiencies, accurate diagnosis of a nematode problem is vital in planning a management approach.

Nematodes are not very mobile, and most are not uniformly distributed. Problem areas within fields develop and change rather slowly. Fields only need to be sampled about every third year if cotton is being grown every year or if cotton is rotated to either soybeans or corn. If vegetables such as watermelon or cantaloupe are grown in the rotation, samples should be taken at the end of the vegetable crop. If cotton follows either rice or grain sorghum, a nematode sample is not necessary.

Sampling fields for nematodes is an inexact science, but if a few precautions are taken, it is possible to obtain a representative sample that can be used reliably for planning management strategies. Laboratory assay results will be of little value, however, if the sample does not represent the field accurately. Fields should be sampled in late summer or fall when nematode populations are at their peak. Probably the optimum time from the standpoint of convenience is soon after harvest, particularly if stalks are shredded immediately after the cotton has been picked. Each sample should represent no more than 20 acres. Areas should be sampled separately if distinctly different soil types are present or if certain areas have shown symptoms that indicate the possibility of nematode damage. A convenient way to permanently subdivide a field into zones that can be sampled individually is to develop a soil electrical conductivity (EC) map (Figure 1). Soil samples should be collected using a

soil sampling tube or other sampling device. Collect soil cores from the row, to a depth of 8-12 inches. A minimum of 20 cores per field or area should be taken. The cores should be mixed together, and at least 1 pint of the mixed soil should be submitted to the nematode lab for analysis.

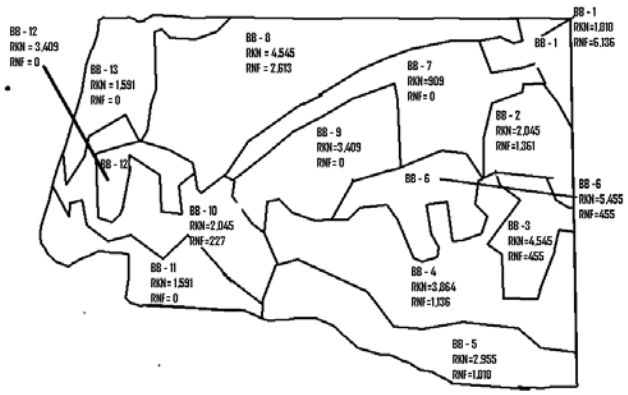

Figure 1. A field that has been subdivided based on soil EC zones. Numbers are the population density of reniform (RNF) or root-knot (RKN) nematodes per 100 cm^3 soil.

Handling and Shipping Nematode Samples

Handling the sample correctly after it is taken is as important as sampling correctly. If the sample is poorly handled the nematodes could die, resulting in an incorrect lab assay. Immediately after the sample is collected and mixed, place it into a plastic bag to prevent drying. Keep the samples out of direct sunlight and away from excessive heat or cold (do not put samples on ice or in a refrigerator). Putting the soil-filled sample bags in an insulated cooler **without ice** is the best method of protecting the samples during short-term storage. Samples should be shipped to the Arkansas Nematode Diagnostic Laboratory, 362 Highway 174 N, Hope, AR 71801, as soon as possible after collection.

Non-vented freezer bags that can be sealed with wire ties are best for nematode samples. In the absence of non-vented freezer bags, standard ziplock bags can also be used but may pop open during shipping. The "zipper type" freezer bags are a better choice. Each bag should be labeled clearly with the field name and any other information that is important for identification of the sample once the results are available. Writing this information on a tag that is attached to the **outside** of the sample bag is preferred. Writing directly on the plastic bags with permanent markers is not a permanent method of labeling the samples – the ink may rub off during transit to the lab. **Never** write the sample information on a piece of paper and place it into the bag with the sample. The moisture from the soil inside the bag will deteriorate the paper almost immediately and result in a sample that cannot be identified in the laboratory.

Each sample needs to be submitted with its own completed sample form. Submission forms are completed online using the University of Arkansas Distance Diagnostics System (UADDS). A user name and password are required to use the site. Individuals should take their samples to the local county Extension office. The county staff will input sample information, print out the documentation and ship it to the Nematode Diagnostic Laboratory. Nematode samples can be submitted to the laboratory through any local Extension office, or they may be shipped directly to the laboratory at the address listed above. A $10 cost-recovery fee is charged for each assay.

Some clientele may want to submit multiple samples at one time. In this case, a user name and password may be granted to an individual, consultant or organization. A user name and password can be requested at the UADDS site – http://www.dddi.org/ua/. Click on "Request an Account," located just under "Login." If the account is approved, a user name and password will be returned by e-mail.

If multiple samples are shipped to the laboratory in the same box, the forms for all samples should be placed together in the box on top of the samples. Do not ship too many nematode samples in the same box. Ten samples per shipping container are ideal. Packing too many samples together can result in damaged boxes during shipping because of their collective weight. The heavier the box, the more likely it will be damaged in transit. This can result in spilling and cross-contamination of the samples within the container. Cross-contaminated samples are not usable and will require that new samples be collected.

Lab Results

The number of each type of nematode that was identified in the sample will be reported by the lab. Nematode numbers are reported as the number present in 100 cubic centimeters (cm^3) of soil (about 3.5 oz). Economic threshold levels for root-knot and reniform nematodes in cotton have been established and are listed in Table 1.

Lab results are usually available within a week of their arrival at the Nematode Diagnostic Laboratory, although during the October-November rush period, reporting time may be longer. Results can be reported electronically by e-mail, fax or surface mail as requested by the client as soon as they are available.

Table 1. Soil population density economic thresholds for cotton nematodes.

Nematode	Time of Year	
	December-May	June-November
	Number/100 cc soil	
Root Knot	NA[1]	50
Reniform	250	1,000

[1] Samples collected December-May are not reliable indications of root-knot nematode problems.

Economic Concerns in Cotton Due to Nematodes

Root-knot nematode (*Meloidogyne incognita*) is a serious problem in Arkansas. This pest has many hosts other than cotton, including soybeans, tomatoes, cucurbits and corn. Worldwide, root-knot may affect more than 3,000 plant species. Nematode feeding causes the cotton plant to form root galls (knots) that can be seen with the unaided eye if the plants are dug up and inspected (Figure 2). The number and size of the galls depend on the population density of nematodes present and the susceptibility of the cultivar. Plants may become stunted and display nutrient deficiencies even when soil test levels of these nutrients are adequate. Infected plants tend to wilt more rapidly than normal, and increasing irrigation may not help. Root-knot damage is likely to be greater in drought-stressed fields and in sandy loam or loamy sand soils. Plants with severe root-knot infection may die prematurely. Root-knot can be particularly severe in combination with certain fungal pathogens. In fields where both root-knot and *Fusarium oxysporum* f. sp. *vasinfectum* (fusarium wilt) are present, the nematode/fusarium wilt complex can result in significant loss of plants by mid-season. Root-knot may also interact with seedling diseases such as *Rhizoctonia solani*, *Pythium* spp. and *Thielaviaopsis basicola*, resulting in very severe stand loss early in the season.

The root-knot nematode life cycle averages 28 days at 80ºF soil temperatures. In Arkansas, root-knot may complete three generations in a crop season. Root-knot prefers lighter soil types and can be severe in fields with coarse-textured sandy soil or in sandy spots within fields (Figure 3). Recent research suggests that soil texture is important in both the economic threshold and the damage potential of this nematode.

Reniform nematode (*Rotylenchulus reniformis*) is a growing problem in Arkansas (Figure 4). Reniform can be a serious pest in both cotton and soybeans. Prior to 1990, reniform nematodes were known to be present in only a few cotton fields in Monroe and Jefferson counties. However, this

Figure 2. Root galling of cotton from root-knot nematode.

Figure 3. Severe root-knot nematode damage in sandy areas of a field.

nematode species has expanded its range throughout the eastern half of the state, and reniform nematodes have now been identified in both cotton and soybean fields in 11 counties from the Louisiana line to the Missouri Bootheel.

Reniform nematodes reproduce rapidly and are usually found at high densities within only a year or two after introduction into a field. It is common to find population densities of 10,000 or greater per 100 cm^3 of soil in Arkansas cotton fields. Once it has been introduced, the reniform may become the dominant nematode in the field. Populations are usually highest in fields in continuous cotton or those rotated with soybeans.

Reniform nematode infection causes root necrosis or death, plant stunting, chlorosis or yellowing of foliage and reduced yields (Figure 5). No visible root symptoms other than smaller root systems are obvious with reniform nematodes. Plant symptoms may be more severe in hot, dry years where the crop is subjected to stress during the season. Severely infected plants may exhibit symptoms of potassium deficiency. The severity of damage due to reniform depends upon population numbers, presence of other pathogens and other in-season field stress. Reniform

Figure 4. Magnified female reniform nematodes.

Courtesy of Charles Overstreet.

Figure 5. Plant stunting caused by the reniform nematode. Normal rows received a nematicide application to control the nematode. *Photo courtesy of W.S. Monfort.*

nematodes may interact with fungal pathogens but not to the same degree as root-knot nematode. They are not restricted to sandy soils and may be found in both clay and silt loam.

Maintaining correct plant nutrient and soil moisture levels may help mitigate plant damage and yield loss but will not correct a reniform problem. The reniform life cycle can take only 25 days, so multiple generations develop over the course of a season. Reniform nematodes survive well and often enter a long-term survival mode (anhydrobiosis) during drought conditions. In addition, reniform nematodes can move vertically in the soil to depths of at least 6 feet, which may also be important in long-term survival. The only way to know for sure that reniform nematodes are present in a field is with a lab assay.

Managing Nematodes

Nematodes cannot be completely controlled, but their populations can be managed. Choosing the correct management option depends upon several factors including the nematode species that is present, general economics of the crop and crop management restrictions. Nematodes can be managed by applying nematicides, practicing crop rotation, proper cultivar selection or fallowing. Generally, a combination of two or more of these methods is most effective.

Nematicides

Nematicides are currently the most popular option for nematode management. Using a nematicide can increase cotton yield 40 to 75 percent in heavily infested fields. Whether or not a nematicide is effective depends upon several factors including soil moisture, soil texture, temperature, timing, the nematicide that is chosen and the nematode population density. Nematicides do not provide 100 percent control of nematodes, and most nematicides are applied prior to or at planting. Nematicides lower root damage levels during the first 4 to 6 weeks of the season, allowing better plant establishment. However, the duration of the nematicide effects on the nematodes is relatively short, and nematode population densities in treated areas may rebound during the last half of the growing season so that populations can be as high, or higher, than non-treated areas by harvesttime.

There are four general application methods for nematicides (Table 2):

1. Injection of soil fumigants prior to planting
2. Application of nematicides directly to planting seed as a seed treatment
3. Application of granular formulations in the planting furrow or as a post-plant side-dress application
4. Foliar spray applications of systemic nematicides post-planting

When choosing a nematicide, several factors must be considered:

- What is the nematode population density?
- Does the application timing of the nematicide fit the farm operation scheduling?
- Is specialized application equipment required and available?
- Will the nematicide likely be cost-effective for the farm operation?
- What are grower preferences on handling safety and convenience?

The fumigant nematicides Telone II, Vapam and K-Pam are the most effective, but they are the most expensive and difficult to use. Fumigants must be injected into the row at least two weeks prior to

Table 2. Cotton nematicide options.

Nematicide	Rate/Acre	Remarks
Telone II[2]	3 - 6 gal	Inject 12 inches below planting depth and seal immediately with appropriate bedding equipment. Wait 14 - 21 days before planting.
Vapam or Kapam[2]	See label.	Inject 12 inches below planting depth and seal immediately. Wait 14 - 21 days before planting.
Temik 15G Temik 15G Lock'n Load *In-Furrow Application*	5 - 7 lbs	Drill granules just below seed line or place in seed furrow and cover with soil. May be used in combination with other products.
Temik 15G Temik 15G Lock'n Load *Sidedress Application*[2]	5 lbs	Only in combination with an at-planting nematicide application. Apply as a sidedress to both sides of the row at about pinhead square. The treatment will likely be more effective if followed by rain or irrigation.
Avicta Complete Pak[1]	Seed Treatment	Commercial seed treatment. May be used in combination with other products.
Aeris[1]	Seed Treatment	Available through commercial seed companies and dealer distributors. May be used in combination with other products.
Vydate C-LV[1] *Supplemental Application*	17 fl oz	Make the first application when cotton is in the 5 - 7 true-leaf stage of growth. Make a second application 7 - 14 days later. Vydate C-LV requires a Temik or Telone II application at or prior to planting.

[1]Use where nematode pressure is low to moderate.
[2]Use where nematode pressure is severe.

Caution: Most nematicides are restricted-use pesticides – for sale and use only by licensed/certified applicators or persons under their direct supervision. **These are dangerous pesticides – use caution in handling and read and follow current label directions.**

planting using specialized equipment. These products, injected into the soil as liquids, turn to a gas and "fumigate" the soil as they emerge. Although most growers apply fumigants in the spring prior to planting, they may also be applied the preceding fall in a minimum-tillage system which will not be disturbed again before planting. Fumigant nematicides are likely to be cost-effective **only at very high nematode population densities** where yield loss has historically been severe.

The granular product, Temik, is the most widely used nematicide in Arkansas. In addition to providing control of nematodes in the soil, Temik also is taken up by the plant and provides systemic protection against certain insects. Temik is less expensive but also less effective against nematodes than the soil fumigants. The product is generally applied in the planting furrow at the time the seeds are planted but can also be applied as a side-dress post-planting application. Temik is most appropriate in fields with **moderately severe** nematode infestations.

The most recent nematicide option is seed treatment. Two products, Avicta Complete Pak and Aeris, contain nematicides as well as chemicals for insect and seedling disease control. Seed treatments are the most convenient method of applying a nematicide, and under **low to moderate** pressure, seed treatments appear to provide adequate nematode protection. However, under severe, or in most cases even moderately-severe nematode pressure, seed treatments do not provide adequate nematode control.

The systemic insecticide/nematicide Vydate C-LV is labeled as a **supplement** to other nematicides for additional nematode suppression. When used as a foliar spray, Vydate C-LV is translocated from the leaves to the roots in concentrations that are high enough to be toxic to nematodes. The degree of additional nematode suppression that is achieved varies from year to year, and yield improvement also may be variable. Consequently, Vydate C-LV should not be used as a stand-alone nematicide.

Resistant Cultivars

Only one cotton cultivar (Stoneville 5599 BR) that is adapted to production in Arkansas is available with moderate resistance to the root-knot nematode, and there are no reniform nematode-resistant cultivars. Several varieties are advertised as being somewhat resistant to fusarium wilt which may aid in situations where the root-knot/fusarium wilt complex exists. However, when wilt-resistant cultivars are infected with root-knot nematodes, the wilt resistance is not fully expressed. Yield losses in this situation may still be unacceptable. In the absence of cultivars that are highly resistant to nematodes, the best rule

of thumb is to select the best cultivar in terms of overall agronomic performance for a particular situation and production system.

Crop Rotation

Crop rotation to poor- or non-host crops suppresses nematode population densities. However, in many cotton production systems, rotation to other crops is not always an option due to economic considerations, land lease or rental agreements or a lack of availability of farm equipment to manage other crops. If crop rotation will be used to manage nematodes, crops for rotation must be chosen carefully and with a knowledge of the nematode species that is present in the field. Both rice and grain sorghum are good options for nematode management. Grain sorghum has not traditionally been a popular crop with producers, but it is a very poor host for root-knot and is likely a non-host for reniform nematodes. The flooded production system that is used in rice will significantly suppress both root-knot and reniform population densities, but few fields in Arkansas that are suitable for cotton production lend themselves well to rice production. Corn is a non-host for the reniform nematode and may be effective in lowering reniform nematode population densities. Unfortunately, corn is not a good option for root-knot management because all commercial field corn hybrids that are popular in Arkansas are susceptible. Both root-knot and reniform-resistant soybean cultivars are available, and these can be useful in rotation systems. The current trend toward earlier maturing soybean cultivars is a concern because many of these cultivars are susceptible to both nematodes.

The number of years that a field should be rotated to a resistant or non-host crop and the frequency of rotation depend on each field situation. Under high nematode pressure, a two-year rotation to a non-host, poor host or resistant cultivar may be necessary to bring population densities below economic thresholds. Under moderate to low levels, one year may be sufficient. Monitoring nematode populations with soil sampling is critical in determining the frequency and length of time that a field will need to be rotated. See Table 3 for suggested rotational crops.

Fallowing Fields

Fallowing fields is a good option for nematode management but not usually practical for cotton producers due to economic considerations and landowner restrictions. Clean fallowing with appropriate burndown or tillage during the fallow period removes host plants from the field and can significantly lower nematode populations.

Table 3. Suggested rotation crops for management of cotton nematodes.

Nematode	Suggested	Not Recommended
Root Knot	Rice Grain Sorghum Resistant Soybeans Peanut	Corn (some hybrids) Susceptible Soybeans Vegetables
Reniform	Corn Grain Sorghum Peanut Resistant Soybean Rice	Susceptible Soybean Vegetables

Other Cultural Practices

The overall production practices for the crop should be considered when managing nematodes. Practicing common sense sanitation to limit the spread of nematodes from one field to another is a sound practice. Wash equipment when moving out of known infested fields into non-infested fields. Wash borrowed or used equipment before entering clean fields. Fall cultivation may reduce nematode numbers by turning the soil to the surface and exposing the nematodes to the sun and winter environment. Choosing furrow irrigation over center pivot irrigation may help by making more water available to the infected plants to minimize water stress. Proper fertilization and irrigation practices as well as good weed control and insect management should always be a goal, particularly where nematodes are also present.

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