TO: **Participants:**
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FROM: Bob Nichols and John Mueller, editors

DATE: March 23, 2010

CC: Kater Hake, Ed Barnes, Kathy Lawrence, Katherine Stevenson, Calvin Perry, Brenda Ortiz, Dana Sullivan, Ed Wrather, Pat O'Leary

SUBJECT: Report of the November 17-18, 2009, Meeting at the Edisto R.E.C., Blackville, South Carolina, on Site-Specific Nematode Management

PURPOSE:

1. Communicate and coordinate research on site-specific management of plant-parasitic nematodes in the Southeast and Mid-South with emphasis on Columbia lance, reniform, and southern root-knot nematodes in cotton.
2. Formulate a consensus extension education approach to site-specific variable-rate nematicide application systems.

Introduction:

Three options exist for the management of row-crop nematodes: crop rotation, host plant resistance, and nematicides. Cotton nematode management has relied extensively on the use of nematicides. Although sources of resistance to reniform and Southern root-knot nematode (RKN) have been released to cotton breeders, the vast majority of commercial cotton cultivars are susceptible to RKN and all are susceptible to reniform nematode. The few cultivars that have been released with resistance to root-knot nematode have exhibited relatively low levels of resistance (Koenning et al., 2004). Whereas resistance may ultimately be the primary management tool for both of these nematodes, cultivars with high-levels of resistance or tolerance will not be available in the short term (five or more years). No resistance or consistent levels of tolerance have been found to Columbia lance nematode. Several excellent rotation schemes are available to help manage all three nematode species. Peanut is a non-host for Columbia lance, reniform and Southern root-knot nematode. However, production economics and logistics limit the number of acres that can be rotated between cotton and peanut. Corn and grain sorghum are effective in reducing reniform nematode populations but are good hosts for the other two species. Soybean is commonly rotated with cotton in many areas, but most soybean cultivars are excellent hosts for all three nematode species. Lack of good cultural management alternatives leaves nematicides as the primary nematode management tool for most cotton growers. Even when good resistant and/or tolerant cultivars are available, nematicides may still be an important tool for management of mixed nematode populations or those dominated by Columbia lance or other migratory nematode species.

The foundation of any nematode management scheme is to utilize fall soil samples to identify the density of each species present in a field. These assayed densities can be compared to established damage thresholds, and nematicides applied only to fields that require treatment. Temik 15G (aldicarb) applied in-furrow, at-planting at a uniform rate across the field is the primary nematicide used in most areas of the country. This treatment costs $15 to $18 per acre depending upon the rate applied. In fields where nematode densities greatly exceed the damage thresholds the fumigant, Telone II (1,3-dichloropropene) applied in-furrow, pre-plant is the most effective available nematicide. Utilization of Telone II requires treatment a minimum of 10 days prior to planting at a cost of $36 per acre plus an additional $10+/acre application cost. Once again the nematicide traditionally has been applied at a uniform rate across the field.

Nematologists have recognized for a long time that damage from most nematode species is not uniform across a field, with damage normally being the worst in sandy areas of the field. Soil texture can influence the level of crop damage from nematodes in several ways. The first is by affecting the geographic distribution of a nematode species. Species such as ring nematode and Columbia lance nematode are found only in soils with greater than 85% sand content. Other nematode species such as reniform or Southern root-knot occur across a much wider range of soil textures. The second way that soil texture influences the level of nematode damage is by creating higher stress levels for the plant. These stresses are a result of poor water and nutrient retention in sandier areas of the field. These stresses exacerbate the damage from almost all nematode species resulting in lower damage threshold values for sandy soil types than soils with higher clay and silt contents. Since the 1960s nematologists and agronomists have tried to predict the occurrence of nematode damage by grid sampling fields. Grid sampling, especially for nematodes, is very expensive. Grids divide a field into artificial units that are not homogenous for soil texture or nematode density. The relatively recent development of the soil electrical conductivity meter and geographical information system (G.I.S.) software allows us to develop accurate soil texture maps in a cost effective manner. The resultant zones are normally irregular in shape, but using G.I.S.-generated software to make application-maps fertilizers, pesticides, and irrigation water can be applied at varying rates to specific soil texture zones.

Early attempts at utilizing soil texture maps to predict plant damage from nematodes centered on the Columbia lance nematode. The Columbia lance management system proved to be an excellent model for predicting pest damage. The nematode’s distribution was restricted to soil textures above 85% sand and these soil types also have the poorest water holding capacity resulting in the greatest plant stress. Nematicide applications to control Columbia lance nematode could be restricted to very sandy sections of fields. In several experiments less than one-third of a field contained Columbia lance nematodes and nematicide applications were reduced accordingly without negatively affecting yield. A very attractive aspect of these results was that the pesticide load for the environment was reduced over 50% in almost all cases.

Subsequent to these successes research has been extended in several states to include the relationship of soil texture to the distribution of Southern root-knot and reniform nematodes and crop responses to nematode damage. A Southeastern regional project, sponsored by the area's Cotton Incorporated State Support Committee is now developing methods for site-specific treatment of reniform nematodes in cotton in the Southeast.

Many questions exist about the relationship between soil texture, nematode distribution, and damage functions. Nematologists need to know if site-specific treatments produce similar results on soils in the Southeast that frequently have a coarse-textured horizon over a subsoil of higher clay content and on those in the Mid-South that are predominantly alluvial and tend to be finer in texture than those of the Southeast. In general, nematode counts on the alluvial soils of the Mid-South have nematode counts that may be10-fold greater than those of the coarser soils of the Southeast. However damage from threshold levels of the pest nematodes on the contrasting soils appear to be similar with respect to the yield differences found between treated vs. untreated plots within a location.

Outstanding questions:

1. Is site-specific nematode management economically advantageous across all soil types?
2. What soil properties should be measured and how should they be utilized?
3. What type of model will best serve growers?
4. Do results from site-specific nematode management trials run in the Southeast and Mid-South share common principles? Can research findings in one area be successfully utilized in the other?

Principles of Site-Specific Nematode Management:

<u>Richard Davis – USDA-ARS and the University of Georgia</u>
Zone Management, Are We Managing Nematodes or Yield?

Seinhorst (1965) described a theoretical relationship between nematode population density and crop yield that is generally accepted by nematologists. The major variables are: 1) <u>maximum yield</u> - yield in the absence of nematodes; 2) the <u>tolerance limit</u> - the threshold level of nematode density at which crop yield begins to decline; 3) the <u>minimum yield</u> - the yield the plant can achieve regardless of nematode numbers; and 4) the <u>slope</u> of the curve - the rate at which yield declines as nematode levels increase.

An unresolved question is whether soil texture affects the values of these four variables. Soil texture directly affects RKN population levels, which are usually lower in heavier soils and in the coarsest sands. Soil texture also directly affects crop growth and yields for example, on Coastal Plain soils, cotton yields are usually inversely related to sand content. In fact, the effect of soil texture on plant growth is generally greater than that of the nematodes on yield. Published research states that RKN have a greater effect on cotton yields in sandier soils (Monfort et al. 2007); however, regression analysis, in the same research, found that interactions between root-knot nematodes and percentage of sand were usually unimportant. Therefore, the yield reduction caused by a given number of RKN was essentially the same regardless of the percentage of sand. Thus over a wide range of soil textures, texture and nematode levels affect cotton yield independently. Other research showed that within a single soil texture, the effects of soil moisture and the effects of root-knot nematodes on cotton yield were usually independent (Davis et al. 2009).

Thus in the relationship described by Seinhorst, soil texture clearly affects actual maximum yield and probably affects the minimum yield also. It is not clear whether soil texture can affect the tolerance limit, but texture probably affects root mass and architecture. Thus the diagnostic value of nematode counts based on soil sampling is not a direct estimate of the parasitic load on a plant. The slope of the curve may be affected at the extremes of percentage of sand (near 0% or 100%), but published research suggests that the slope is generally not affected much by soil texture (Monfort et al. 2007).

Ahmad Khalilian – Clemson University Cooperative Extension Agricultural Engineering
Using Soil Electrical Conductivity Meter Readings for Nematode Management

Predicting nematode distribution by utilizing the strong correlation of soil texture and nematode populations has been common to most projects on the utilization of precision application technologies for nematode management. An efficient and economical means to determine soil texture without the cost and time required by grid sampling was needed. Soil electrical conductivity (EC) is strongly correlated to soil particle size and, therefore, soil texture. Sand, silt, and clay exhibit low, medium, and high electrical conductivity, respectively. Equipment is commercially available from Veris Technologies for rapid and accurate determination of soil texture within fields by using the correlation of electrical conductivity with texture. The mapping system is a sensor carriage with three sets of straight-blade disk coulters. These coulters serve as electrodes from which soil EC measurements are made as the sensor travels across the field. The Veris unit can simultaneously map soil EC at two depths, approximately, 12 and 36 inches, and the data can be linked to a global positioning systems (GPS) system to generate a continuous soil texture map. Using the Veris EC sensor a 20-acre field can be mapped in less than 3 hours.

Extension needs:
We need an extension bulletin on soil electrical conductivity, how to use the Veris equipment, and how to interpret the results.

Site-Specific Management of Nematodes on Coarse-Textured Soils – Southeast:

<u>Bob Kemerait – University of Georgia Cooperative Extension Service</u>
Site-Specific Root-Knot Nematode Project - Georgia

In 2005, a project was initiated by the Georgia Cotton Commodity Commission, and subsequently administered and funded by Cotton Incorporated, to develop techniques to use the Veris sensor to determine soil texture and map nematode populations. The project was expanded in 2007 to use soil and site data to create management zones and identify site-specific programs for nematode management. Research by Brenda Ortiz and others has determined that soil and site variables are quantitatively associated with RKN populations (Ortiz et al. 2008). These research projects developed field mapping techniques and used them in concert with nematode counts to define management zones to estimate the site-specific risk of yield loss due to RKN. At present, we have further goals to: 1) Validate the Risk Management Zones developed by these projects; 2) Further refine the criterion for defining and drawing such Risk Management Zones; and 3) Determine the effects of nematode populations on cotton fiber quality as well as yield.

<u>Richard Davis – USDA-ARS and the University of Georgia</u>
Southeast Regional Soil-Specific Reniform Nematode Project - Georgia

A second year of a field site in Georgia was completed in a project evaluating the use of nematode management zones in cotton fields infested with the reniform nematode. The nematode management zones in this project were created by the same process used to develop the RKN management zones. We used soil EC, elevation, and slope to draw zones that minimized variation in these factors within a zone, and maximized their differences among zones. The same experiment is also being done at two sites in Alabama and another in North Carolina to gather information from a wider range of soil conditions. Five nematicide treatments, ranging from an untreated control to a high rate of Telone II plus Temik, were replicated within each of the three zones. We do not yet have yield data for 2009, but nematode levels differ among the zones. The 2008 data suggests that the effects of the nematicide treatments were not influenced by the zones. While results to this point suggest that our method of delineating the management zones can be an effective guide to targeted nematode sampling, the data suggest that the choice of nematode treatment and the effectiveness of the treatment are independent of the zones over the range of conditions tested.

<u>Steve Koenning – North Carolina State University</u>
Southeast Regional Soil-Specific Reniform Nematode Project in North Carolina

Results of a project on the effect of soil factors on crop yields, reniform nematode distribution, nematode damage to cotton, and the response of the nematodes and crop to nematicide treatment were reported. A common experiment is being sponsored by the Cotton Incorporated State Support Committees of the Southeastern region (VA-AL) and is being done in AL (2 locations), GA, and NC (total of four sites in 2009). Twodimensional soil electrical conductivity at the 12-inch and the 36-inch depths of fields that have different soil types was measured using a Veris, mobile soil-electrode. The soil and site data were grouped according to similarity and field-treatment zones delimited. Nematicide treatments were replicated across zones. Nematodes were counted before and following treatment and cotton yields collected. Preliminary results suggest that treatments were similarly effective regardless of management zones. These results generally agree with Richard Davis' Georgia data.

Scott Moores – Auburn University
Southeast Regional Soil-Specific Reniform Nematode Project in Alabama

Effects of Soil Type on the Reproduction of *Rotylenchulus reniformis,* 2008
Six soil types common to Alabama were evaluated for their effects on the reproduction of *R. reniformis* in a micro-plot trial under irrigated and non-irrigated conditions in 2008. The soil types evaluated were a Dothan sandy loam (sand (s)-silt (si)-clay(c) = 57-28-15), a Decatur silt loam (s-si-c = 23-49-28), a Hartsells fine sandy loam (s-si-c = 51-38-11), a Ruston very fine sandy loam (s-si-c = 59-33-8), a Pacolet sandy loam (s-si-c = 59-15-26), and a Vaiden clay (s-si-c = 5-42-53). Two thousand vermiform life stages of *R. reniformis* were added to each plot at planting. Populations of *R. reniformis* were evaluated at mid-season and at harvest and seed cotton yields recorded.

Soils with higher clay and silt content were more conducive to *R. reniformis* population increase. Populations of *R. reniformis* in the irrigated trial were significantly higher in those soils that contained silt + clay contents of greater than 50% (Decatur silt loam and Vaiden clay) compared to those soils that did not. Silt and clay content of the soils were positively correlated with populations of *R. reniformis* at both mid-season and harvest, while sand content was negatively correlated. Yields were not correlated to *R. reniformis* populations within the irrigated trial, but were correlated with the clay content of the soil. Conversely, no effects from soil composition were observed on *R. reniformis* populations within the non-irrigated trial. Cotton yields within the non-irrigated trial were negatively correlated with populations of *R. reniformis.* Under natural conditions, the Ruston very fine sandy loam supported the highest *R. reniformis* populations and resulted in the lowest cotton yields while the Hartsells fine sandy loam supported the lowest *R. reniformis* populations and the highest cotton yields.

Soil-Specific/Variable Rate Nematicide Trial, 2009
A trial to evaluate the effectiveness of nematicides to manage *R. reniformis* within three zones delineated by soil electrical conductivity was established in 2009 near Atmore, AL. Nine nematicides or combinations of nematicides were chosen for evaluation against an untreated check: 1, 3-dichloropropene (Telone II®) applied at 4.5, 3.0, and 1.5 gal/acre; aldicarb (Temik 15G) applied at 3.5 and 7.0 lbs./acre; Avicta Complete Pak seed treatment; Avicta Complete Pak seed treatment + aldicarb 3.5 lbs./acre; Avicta Complete Pak seed treatment + Vydate CL-V 16 oz/acre; Avicta Complete Pak seed treatment + aldicarb 3.5 lbs./acre + Vydate CL-V 16 oz./acre. The trial was a strip plot trial with each plot being 6 rows by 50 ft. replicated 5 times within each zone. The Telone II treatments were injected 18 in. deep 6 weeks prior to planting (30 Apr).

Cotton (DPL-161B2RF) was planted on 10 June. Vydate CL-V was applied to selected treatments 6 weeks after planting (22 July). Soil samples for nematode analysis were collected at planting, 30 and 60 DAP, and at harvest. Plant heights were measured at 60 DAP. Zones were labeled low, medium, or high risk dependent on populations of *R. reniformis* at plant.

Reniform nematode numbers at plant ranged from 0 – 150 nematodes per $150cm^3$ of soil in the low risk zone, 250 – 1,000 nematodes per $150cm^3$ in the medium risk zone, and greater than 1,000 nematodes per $150cm^3$ of soil in the high risk zone. All nematicides performed differently in each zone. Within the high risk zone, Temik 15G 7.0 lbs./acre and Avicta Complete Pak + Temik 15G 3.5 lbs./acre significantly lowered *R. reniformis* populations from those at planting compared to all other nematicide treatments and the untreated control. At 60 DAP, nematode populations were significantly lowered in comparison to 30 DAP populations in the Avicta Complete Pak + Temik 15G 3.5 lbs./acre + Vydate CL-V treatment. All three Telone II rates produced plants at 60 DAP that were significantly taller than all other treatments and the untreated control. *Rotylenchulus reniformis* populations within the medium risk zone were significantly lowered at 30 DAP from those at planting by Temik 15G 7.0 lbs./acre and Avicta Complete Pak compared to the untreated control. No nematicide treatment significantly lowered nematode populations between 30 and 60 DAP compared to the untreated control. All three rates of Telone II produced significantly taller plants at 60 DAP compared to all other treatments and the untreated control. Within the low risk zone, no nematicide lowered *R. reniformis* populations in comparison to the untreated control at either 30 or 60 DAP. Plant heights at 60 DAP were significantly taller in the Telone II 4.5 gal./acre treatment compared to all other nematicide treatments and the untreated control. Telone II 3.0 gal./acre and Temik 15G 3.5 lbs./acre produced significantly taller plants at 60 DAP compared to the untreated control.

Management of Nematodes on Alluvial Soils with Varying Textures – Mid-South:

<u>Scott Monfort</u> – University of Arkansas Cooperative Extension Service

Research has been done in Arkansas from 2002 to 2008 on the use of precision agriculture technologies to identify and manage nematodes in cotton (Monfort et al. 2007). The results of the research indicate that soil texture is the most important variable in understanding the population dynamics and damage potentials of root-knot nematode. Based on the results, we learned that through understanding how soil textures impact both the nematode and the development of the plant, a more effective management strategy can be constructed. Through these efforts, we also have developed site-specific application equipment with the help of industry and other colleagues at Clemson University and Louisiana State University. We have conducted many research trials from 2005-2009 evaluating site-specific placement of nematicides using management zone nematode sampling based soil texture. Thus far, our efforts have shown producers can reduce nematicide use by 30% without reducing yield.

<u>Charles Overstreet</u> – Louisiana State University Cooperative Extension Service

Results of several years' research on formation of nematode management zones were discussed. Initial results indicated that the use of soil EC to determine the distribution of soil textures within a field was useful to identify areas that were infested by RKN. A number of experiments using the soil fumigant Telone II were conducted in fields that had RKN distributed across a range of soil textures. Some of the textural zones that had nematodes did not show any positive response to the application of the fumigant, suggesting that soil texture could be involved in ameliorating nematode injury. A number of other studies were later conducted that showed this same type of differential response to nematodes and a lack of response to fumigation for certain soil textures within a field. We now are looking at using a combination of EC, nematode populations with soil zones, and/or previous yields to develop risk and management zones. The use of verification strips (fumigated and non-fumigated rows through the various soil zones) has proven to be a very useful method in defining the areas within a field that would require treatment

Implementation of Site-Specific Nematode Management:

Will Henderson – Clemson University Cooperative Extension Service

Clemson University has done field research at grower locations using zone management for nematode control. The typical treatments are Aeris® or Avicta® seed treatment (non-site-specific) and Temik 15G at 0, 3, or 6 lbs./acre. At some locations, Telone II has been applied. Observations suggest that application of Telone II at 6 gal./acre may have an effect for as much as two years. In addition, Mr. Henderson and Dr. Khalilian now are doing extension demonstrations with variable rate application of Temik 15G at 0, 3, 5, and 7 lbs./acre.

James Thomas – Independent Crop Consultant
What will Growers Use? Buy?

Many South Carolina growers have an interest in zone management of nematodes. As a consultant, Mr. Thomas has worked with growers by starting on problem fields and sampling the lightest soils. He has recommended application of Telone II to certain areas within fields and had good success. At this time, some growers will pay up to $5/acre for Veris mapping, preparation of a field map of soil EC with 'Farm Works,' and will purchase 'on/off' controllers for field application equipment.

Action Agenda:

1a. Steve Koenning will present the 2009 results of the Southeast Regional Project, sponsored by Cotton Incorporated Southeast State Support Committees, at the scheduled review on Jan. 21, 2010, at the Westin in Charlotte, NC. Kathy Lawrence and Richard Davis will provide Steve with data and assistance in preparing the report. The researchers will request renewal for 2010 and will consider alerting the Committee that they may request a funded extension through 2011. Please copy me on all data and communications.

1b. (Data were assembled. Steve Koenning made the presentation. It was well received and the project was funded for 2010 and extended through 2011.)
Tangible Accomplishments of the Regional Project in Progress:
We anticipate submission of the two-year, NC micro-plot data for publication in 2010, and that from the three-year, micro-plot experiment done in AL to be submitted for publication in 2011.

3. Bob Nichols is responsible to see that nematologists have ready access to a summary of the results of the multi-year project on soil-specific treatment of RKN that was sponsored by the Georgia Cotton Commission and later by Bayer Crop Sciences. Several individuals contributed to this effort, prominently including Brenda Ortiz. Contributions from all who have contributed will be recognized in the publications resulting from this funding.

4a. Scott Monfort and Charles Overstreet will summarize their data on the effects of soil texture on nematodes and nematicide treatment.

4b. (Since the Edisto meeting, Cotton Incorporated Louisiana State Support Committee has voted funding to Charles to collect and analyze soils from four locations where he has recently worked.)

5. John Mueller will coordinate an effort to prepare an extension bulletin on how to collect and utilize soil data to selectively direct treatment. He will be assisted by Bob Kemerait, Will Henderson, Scott Monfort and Charles Overstreet. There is a further intention to create a consensus method and develop a multi-state training session. The cooperators may develop a proposal to acquire funding to support such an effort.

6. The group felt that further communication and coordination was in order. Richard Davis will organize and host a meeting of this group in Tifton, GA, on Tuesday-Wednesday, November 30-December 1, 2010.

Citations:

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