

1324 Recent Advances in Nematode Management in U.S. Cotton

Dr. Robert Nichols , Cotton Incorporated, Cary, NC

The two most economically important plant-parasitic nematodes infesting cotton (*Gossypium hirsutum*) in the United States are the root-knot (*Meloidogyne incognita*) and the reniform (*Rotylenchulus reniformis*) nematode. The common means of managing these pests is use of in-furrow or seed-treatment nematicides, or by rotation with non-host crops or resistant cultivars of crops grown in rotation. Until 2007, low grain prices limited use of corn (*Zea mays*) or soybean (*Glycine max.*) in cotton rotations. Nematicides are not fully effective in preventing damage to cotton, in part because they do not persist in the soil or the cotton seedling at effective concentrations for more than about 30 days after application. Recent research suggests that nematicides may be more advantageously targeted by considering the yield potential of the cotton on the specific soil as well as the population of the pest nematode species. While root-knot resistant cotton cultivars have been available for some time, they are only partially effective and/or selectively adapted across the diverse growing conditions of the U.S. Cotton Belt. Reniform resistant cotton cultivars have been wholly unavailable. Recent work by USDA-ARS and public universities has resulted in superior agronomic germplasm releases with high levels of root-knot resistance and the first release of reniform resistant germplasm. The reniform resistant releases were derived from *Gossypium longicalyx* by means of a triple-species hybrid. In both cases, the releases are, or shortly will be, accompanied by publication of genetic markers closely linked to the resistance genes.

Keywords: Cotton, Crop Rotation, *Gossypium hirsutum*, Host Plant Resistance, *Meloidogyne incognita*, Nematicides, Nematodes, Reniform nematode, Root-Knot Nematode, *Rotylenchulus reniformis*.

INTRODUCTION

The U.S. Cotton Belt spans the Southern United States from the San Joaquin Valley of California to Southeastern Virginia. Major cotton producing areas are found in Texas, the lower Mississippi Valley, and the southeastern Coastal Plain. In recent years, approximately 5.5 to 6.0 million hectares have been grown annually. Cotton is grown on many different soil types, ranging in texture from coarse loamy sands to fine alluvial clays. Across the region, growing seasons range from approximately 130 frost-free days to areas where frost does not occur in certain years. Large areas of the Cotton Belt are infested with one or more species of plant-parasitic nematodes that damage cotton. The root-knot nematode is wide spread and causes the most damage (Blasingame, 2006). It is especially prevalent in the Southeast, Texas, and California. Over the last decade, the reniform nematode has expanded its range substantially in the Mid-South region and now causes greater losses than does the root-knot nematode in the states of Alabama, Arkansas, Louisiana, Mississippi, and Tennessee (Heald & Robinson, 1990; Blasingame, 2006). Other plant parasitic nematodes infesting cotton include the sting nematode (*Belonolaimus longicaudatus*) and Columbia lance nematode (*Haplolaimus columbus*) (Koenning et al., 2004).

With such wide variations in climate, soil, yield potential, nematode species and pest populations, there are many different possibilities for crop damage that each require a different management approach to preserve cotton yields. As with any crop, cotton's yield

potential is determined by cultivar and environment. The crop responds to water and plant nutrients, and must be protected from weeds, insects, and diseases, including nematodes. Controlled experiments estimate that yield losses in untreated fields of fully susceptible cotton cultivars, where pest nematodes are above state-recommended thresholds, are often 90 to 180 kg lint/ha and can be greater (Orr & Robinson, 1984; Kinloch & Rich, 1998; Overstreet et al., 2001; Kemerait et al., 2006). Practical field management of plant parasitic nematodes in agronomic crops depends on crop rotation, chemical treatment, or utilization of resistant cultivars (Barker & Koenning, 1998; Barker et al., eds., 1998).

CROP ROTATION

Rotating a crop, with a second crop that is not susceptible to the same pest nematode as the first, often shows yield increases for both crops compared with the yields produced by the same two crops grown separately in continuous mono-cultures (Trivedi and Barker, 1986). The principle of alternating cotton with other crops that are not hosts, or are poor hosts of a pest nematode species that infests cotton, is well established. In crop rotation studies, plant-parasitic nematode populations often exhibit dynamics that correspond with crop damage and yield trends (Johnson et al., 1975; Kinloch, 1983; Kirpatrick & Sasser, 1984). Crops that suppress reniform nematodes for a succeeding cotton crop include corn or peanuts (*Arachis hypogaea*), and peanuts or resistant soybean cultivars suppress root-knot nematodes for cotton (Noe et al., 1991).

Considering the recognized benefits, crop rotations seem to have been under-utilized by large-scale U.S. cotton growers. Limitations on the use of crop rotations include crop and cultivar adaptation, overlapping susceptibilities of crop pests other than nematodes, costs of specialized planting or harvesting equipment, and the relatively lower returns that might be achieved from certain of the possible rotation crops relative to those of cotton. In recent years, the main factor limiting the planting of corn, sorghum (*Sorghum bicolor*) or soybean in rotation with cotton appears to have been the relative prices of the respective crops, and the consequent returns that may have been achieved from growing them. In fact, the U.S. crop hectares planted in 2007 show that there is no reluctance to plant corn in the lower Mississippi Valley in preference to cotton when corn prices are high and cotton prices are low.

NEMATICIDES

In the mid-20th century, several highly-effective fumigant nematicides, including methyl bromide, ethylene dibromide (EDB), and dibromo-chloro-pentene (DBCP), were registered for use on many crops in the U.S. With the exception of 1,3 dichloropene (1,3-D), fumigant use is no longer permitted for cotton. Nematicides registered in the 1960s and 1970s, notably the carbamate insecticide/nematicide aldicarb, were initially discovered as insecticides and only subsequently determined to have nematicidal activity. In the past decade, by far the most commonly used nematicides in cotton were aldicarb, and 1,3-D. In 2000, aldicarb was used on approximately 30% of U.S. hectares (Koenning, 2004). From the 1970s until the present, no new chemical nematicides were registered in the U.S., except for the two seed-treatment nematicides, abamectin and thiodicarb, registered in 2006 and in 2007, respectively. Greenhouse and field research suggests that commercially treating cotton planting seed with abamectin is equivalent in its negative effect on pest nematodes and its positive effect on cotton yields to applying 840 gm a.i./ha of aldicarb as an in-furrow granular treatment (Monfort et al., 2006; Kemerait et al., 2006).

U.S. growers have access to effective nematicides, but may not efficiently place them for maximum economic benefit. Crop yield potential depends on soil type, and few fields are comprised of only a single soil. Similarly, the properties of soil-applied materials interact with the soils where they are applied. Moreover, the distribution of pest nematodes within fields is not uniform. Commercial access to global positioning technology created the opportunity to operate agricultural equipment and manage fields at scales smaller than whole-field treatment. Replicated strip trials on fields comprised of different types of alluvial soils have clearly shown that cotton growth and crop response to nematicides depends on soil factors (Overstreet et al., 2005; Overstreet et al., 2006). In addition, nematologists have successfully applied nematicides at varying rates for the purpose of treating non-uniform distributions of pest nematodes (Wheeler et al. 1999; Wrather et al., 2002). Greater use of site-specific nematicide applications might be made, if information was available to better predict where within fields economic responses to nematicide treatments would result. A limiting factor has been economically determining where the pest nematode populations are sufficient to cause economic damage (Wheeler et al., 2006).

An essential problem for all seed and soil applied nematicides is that the nematicidal treatment must reach the roots where the nematodes feed. Fumigant nematicides are applied pre-plant. Obviously seed treatments are applied at planting. The great majority of granular nematicide treatments are also applied while planting. Since the root system develops during the growing season, treatments applied pre-plant or at-planting come into direct contact with cotton seedling roots, but impact later-emerging root growth to a much lesser extent. Nematode populations are low early in the growing season and increase as the volume and biomass of cotton roots expand (Starr, 1989). Therefore, much of the plant biomass where nematodes may feed is never directly exposed to seed or soil applied nematicides at biologically effective concentrations. In contrast, we might reasonably expect that strong host-plant resistance mechanisms would be expressed at the sites of action throughout the growing season.

HOST PLANT RESISTANCE

Resistance to root-knot nematode (RKN) was developed in cotton by USDA-ARS over 30 years ago (Shepherd 1974a, 1974b). But the resistance has not been widely used, and the level of expression in the root-knot resistant commercial cultivars has not been equal to that of the original release, 'Auburn 623 RNR.' The variability in nematode reaction among plants and the labor required to assess the phenotype of the crosses have been stated as the principal impediment to more general use of root-knot resistance by commercial planting seed companies. Whereas, sources of root-knot nematode resistance have been available to cotton breeders, no high-levels of resistance to reniform nematode has been identified in Upland cotton (Weaver et al., 2007). However, recent work has resulted in breakthroughs in identification and *de novo* development of nematode resistance sources and genetic markers closely linked to the resistance genes. Germplasm and candidate genetic markers now are available in the public sector to use for development of cotton cultivars with high levels of resistance to both root-knot and reniform nematodes.

Recent cotton breeding has resulted in release of six advanced cotton germplasm lines with high levels of root-knot nematode resistance (Creech et al., 2007). These lines are derived from crosses made with resistance sources originally bred by Dr. R. Shepard (Shepard, 1974a). Several recent publications have identified genetic markers closely linked to major genes associated with the resistance in Auburn 623 RNR and in the resistant Acala 'NemX' (Wang et al. 2006a, 2006b and Wang & Roberts 2006a and 2006b, and Shen et al., 2006,

Ynturi et al., 2006). Thus, we now have advanced root-knot resistant Upland cotton germplasm and published genetic markers that may serve to facilitate breeding of commercial cultivars.

Virtual immunity to reniform nematode found in the wild, diploid ($2n=26$) cotton relative, (*Gossypium longicalyx*), has been introgressed to tetraploid ($2n=52$) Upland cotton lines by backcrossing germplasm from two synthesized triple-species hybrids, HLA = (*G. hirsutum* x *G. longicalyx*)² x *G. armourianum*) and HHL = (*G. hirsutum* x *G. herbaceum*)² x *G. longicalyx*). Release of seed has been approved (St. John, et al., 2007). Inheritance of the resistance suggests control by single dominant gene. Closely linked genetic markers have been identified (Dinghe et al., in preparation).

REFERENCES

Barker, K.R. and S.R. Koenning. 1998. Development of sustainable systems for nematode management. Annual Review Phytopathology 36:165-205.

Barker, K.R., G.A. Pederson, and G.L. Windham, editors. 1998. Plant and Nematode Interactions. 771 pp. American Society of Agronomy Inc. and Crop Science Society of America Inc. Publishers. Madison, Wisconsin.

Blasingame, D. 2006. 2005 Cotton Disease Loss Estimate. Proceedings of the 2005 Beltwide Cotton Conferences. 156-158. CD ROM National Cotton Council. Memphis, Tennessee.

Creech, R.G., J.N. Jenkins, J.C. McCarty, R. Hayes, J.B. Creech, D. Haire, and R. Cantrell. Registration of MS-01RKN, MS 24RKN, MS-33RLN, MS-35RKN and MS-37RKN Cotton Germplasm Lines with Resistance to Root-Knot Nematode. (Accepted by the Journal of Crop Registrations for publication in the September 2007 issue.)

Dighe, N., A. Bell, F. Robinson, M. Menz, and D. Stelly. Tagging and mapping of the reniform nematode resistance gene introgressed from wild diploid, *G. longicalyx* into Upland cotton, *G. hirsutum*. (In preparation.)

Heald, C.M. and A.F. Robinson. 1990. Survey and Current Distribution of *Rotylenchulus reniformis* in the United States. Supplement to the Journal of Nematology 22(4S):695-699.

Johnson, A.W., C.C. Dowler, and E.W. Hauser. 1975. Crop rotation and herbicide effects on population densities of plant-parasitic nematodes. Journal of Nematology 27:457-464.

Kemerait, R.C., P.H. Jost, S.M. Brown, T.W. Green, B.R. Mitchell, W.E. Harrison, C.L. Brewer, R.G. McDaniel, D.G. Spaid, and K.D. Mickler. 2006. Assessment of Seed Treatments for Management of Nematodes in Georgia. Proceedings of the 2006 Beltwide Cotton Conferences. 144-148. CD ROM National Cotton Council. Memphis, Tennessee.

Kinloch, R.A. 1983. Influence of maize rotations on the yield of soybean grown in *Meloidogyne incognita* infested soil. Journal of Nematology 15: 398-405.

Kinloch, R.A. and J.R. Rich. 1998. Responses of Cotton Yield and *Meloidogyne incognita* Soil Populations to Soil Applications of Aldicarb and 1,3-D in Florida. Journal of Nematology 30(4S): 639-642.

- Kirkpatrick, T.L. and J.N. Sasser. 1984. Crop rotation and races of *Meloidogyne incognita* in cotton root-knot management. *Journal of Nematology* 16: 323-328.
- Koenning, S.R., T.L. Kirkpatrick, J.L. Starr, J.A. Wrather, N.R. Walker, and J.D. Mueller. 2004. Plant-Parasitic Nematodes Attacking Cotton in the United States. *Plant Disease* 88(2): 100-113.
- Monfort, W.S., T.L. Kirkpatrick, D.L. Long, and S. Rideout. 2006. Efficacy of a Novel Nematicidal Seed Treatment against *Meloidogyne incognita* on Cotton. *Journal of Nematology* 38(2): 245-249.
- Niu, C., D.J. Hinchliffe, R.G. Cantrell, C. Wang, P.A. Roberts, and J. Zhang, 2007. Identification of molecular markers associated with root-knot nematode resistance in Upland cotton. (Accepted by *Crop Science* for publication in the March-April 2007 issue.)
- Noe, J.P., J.N. Sasser, and J.L. Imbriani. 1991. Maximizing the potential of cropping systems for nematode management. *Journal of Nematology* 23: 353-361.
- Orr, C.C. and A.F. Robinson. 1984. Assessment of cotton losses in Western Texas caused by *Meloidogyne incognita*. *Plant Disease* 68: 284-285.
- Overstreet, C., E.C. McGawley, and G.W. Lawrence. 2001. Telone II for management of the reniform nematode in cotton during 1999-2000 in northern Louisiana and southern Mississippi. *Phytopathology* 91:S 140.
- Overstreet, C., M. Wolcott, G. Burris, D.R. Cook, D. Sullivan, and G.B. Padgett. 2006. Telone Application against Root-knot Nematode in Tensas Parish, Louisiana. Proceedings of the 2006 Beltwide Cotton Conferences. pp. 171-176. CD ROM National Cotton Council, Memphis, Tennessee.
- Overstreet, C., M. Wolcott, E. Burris, D. Cook, D. Sullivan, and G.B. Padgett. 2005. Evaluating Cotton Nematicide Response across Soil Electrical Conductivity Zones Using Remote Sensing. Proceedings of 2005 Beltwide Cotton Conferences. pp 215-220. CD ROM National Cotton Council. Memphis, Tennessee.
- Shen, X., G. Van Becelare, P. Kumar, R.F. Davis, O.L. May, and P. Chee. 2006. QTL mapping for resistance to root-knot nematodes in the M-120 RNR Upland cotton line (*Gossypium hirsutum* L.) of the Auburn 623 RNR source. *Theoretical & Applied Genetics* 113: 1539-1549.
- Shepherd, R.L. 1974a. Transgressive segregation for root-knot nematode resistance in cotton. *Crop Science* 14: 872-875.
- Shepherd, R.L. 1974b. Registration of Auburn 623 RNR germplasm (Reg. no. GP20). *Crop Science* 14: 911.
- St. John, J.B., M.C. Hussey and P.F. O'Leary. Notice of Release of two Upland Cotton Germplasm Lines Resistant to Reniform Nematode. (Approved April 2, 2007.)

Starr, J.L. 1989. Population Dynamics of Root-Knot Nematodes. Southern Cooperative Series Bulletin No. 336. Texas Agricultural Experiment Station, College Station, Texas. 21 pp.

Trivedi, P.C. and K.R. Barker. 1986. Management of nematodes by cultural practices. *Nematropica* 16: 213-236.

Wang, C., W.C. Matthews, and P.A. Roberts. 2006b. Phenotypic expression of *rkn1*-mediated resistance in *Gossypium hirsutum* populations. *Journal of Nematology* 28: 250-257.

Wang, C. and P.A. Roberts. 2006a. A Fusarium wilt resistance gene in *Gossypium barbadense* L. and its effect on root-knot nematode-wilt disease complex. *Phytopathology* 96: 727-734.

Wang, C. and P.A. Roberts, 2006b. Development of AFLP and derived CAPS markers for root-knot nematode resistance in cotton. *Euphytica* 152: 185-196.

Wang, C., M. Ulloa, and P.A. Roberts. 2006a. Identification and mapping of microsatellite markers linked to the root-knot nematode resistance gene *rkn1* in Acala NemX cotton (*Gossypium hirsutum* L.) *Theoretical & Applied Genetics* 112: 770-777.

Weaver, D.B., K.S. Lawrence, and E. van Santen. 2007. Reniform nematode resistance in Upland cotton germplasm. *Crop Science* 47(1): 19-24.

Wheeler, T. A. 2006. Nematode Sampling: The Limiting Factor to Variable Rate Application. Proceeding of the 2006 Beltwide Cotton Conferences. pp.160-163. CD ROM National Cotton Council. Memphis, Tennessee.

Wheeler, T.A., H.W. Kaufman, B. Baugh, P. Kidd, G. Schuster, and K. Siders. 1999. Comparison of variable and single-rate applications of aldicarb on cotton yields in fields infested with *Meloidogyne incognita*. Supplement to the *Journal of Nematology* 31: 700-708.

Wrather, J.A., W.E. Stevens, T.L. Kirkpatrick, and N.R. Kitchen. 2002. Effects of site-specific application of aldicarb on cotton in a *Meloidogyne incognita* infested field. *Journal of Nematology* 34: 115-119.

Ynturi, P., J.N. Jenkins, J.C. McCarty, Jr., O.A. Gutierrez, and S. Saha. Association of root-knot nematode resistance genes with SSR markers on two chromosomes in cotton. *Crop Science* 46(6): 2670-2674.