THE USE OF TEMIK® 15G ON COTTON AND SOYBEAN IN THE SOUTHEAST

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Abstract

The recent voluntary stepwise withdrawal of Temik® 15G by Bayer CropScience has brought renewed interest in developing new options for nematode management in cotton throughout the cotton belt. Temik® 15G provided a very cost effective level of control for most nematode species under a wide range of environmental conditions, cropping systems and levels of nematode pressure. At the present time no single management tool is available to cost effectively replace Temik® 15G. Telone® II is a highly effective nematicide but is not as cost effective or convenient to use as Temik® 15G. Current seed treatment nematicides are convenient to use, however they lack the ability to control higher levels of nematodes. Host plant resistance is a developing option but currently only cultivars partially resistant to Southern root-knot nematode are commercially available. Nematode management in the absence of Temik® 15G will rely on improved integration of the usage of available nematicides with crop rotations and partially resistant cultivars. The key to all nematode management is to have each plant produce a healthy tap root of suitable length (usually 12 inches or longer) to obtain water and nutrients throughout the growing season. This requires nematode management primarily during the first 3 to 4 weeks of the growing season. The key to all effective nematode management programs is knowledge of the species and density of nematodes present in each field. The only way to obtain this knowledge is through a nematode sampling program. Development of innovative management schemes and products will require substantial financial and time inputs from private industry, universities, organizations such as Cotton Incorporated, and federal research programs.

Introduction

Plant-parasitic nematodes are economically important pests of cotton throughout most of the cotton belt. According to yield loss estimates from the Beltwide Cotton Disease Council nematode-induced yield losses have averaged almost 5.0% for the last 10 years. These losses are especially high in the Southeastern United States.

Temik® 15G has been the primary management tool for plant-parasitic nematodes in cotton for almost 40 years. South Carolina grew approximately 190,000 acres of cotton in 2010. According to sales figures and estimates 85 to 90% of the cotton acres were treated with approximately 5.0 lbs of Temik® 15G applied in-furrow at-planting. The figures for Temik® 15G use on soybean are similar with 35% of the 500,000 acres of cotton grown in South Carolina treated at-planting in-furrow with 3.0 to 4.0 lbs of Temik® 15G (Jerry Adams, Bayer CropScience, personal communications). The at-planting use of Temik® 15G highlights a very important part of nematode management for both of these crops. Cotton and soybean are both strongly tap rooted crops. These tap roots reach most of their length in the first 3 to 4 weeks of the growing season. Once they have reached full length they are able to sustain much more damage from nematodes before yields are affected. This is why all successful nematode management schemes must control nematode damage in the first 3 to 4 weeks of the growing season.

Discussion

Nematode Species

Not all species of nematodes are capable of consistently producing yield losses on cotton. The primary nematode species on cotton are the Southern root-knot nematode (*Meloidogyne incognita*), the reniform nematode (*Rotylenchulus reniformis*) and the Columbia lance nematode (*Hoplolaimus columbus*) (Bridge and Starr 2007, Overstreet & McGawley 2001a, Whitehead 1988). Sting nematode (*Belonolaimus longicaudatus*) can be a very severe pathogen on cotton however it occurs only in very sandy soils and is not common in most areas (Overstreet & McGawley 2001b). Lesion nematodes (*Pratylenchus spp*.) are very common however in general they are believed to be less pathogenic than root-knot, reniform or Columbia lance nematodes (Starr and Page 1990). Species such as stunt, dagger, and stubby root are capable of causing damage to cotton only when present at very high densities (Bridge 1992, Dickerson et al. 2000). Ring and spiral nematodes are commonly seen in many cotton fields however they are rarely associated with significant damage (Dickerson et al. 2000). In many instances they are probably feeding on weeds present in the fields.

Distribution and frequency of nematodes

The distribution of nematodes is determined by many factors. Soil texture, crops grown and the temperature and rainfall distribution of an area are some of the most important factors. Distribution of some species such as sting nematodes is limited strictly to very sandy soils. Other species such as Columbia lance nematode are restricted to soils with sand contents of at least 75% (Mueller et al. 2010). Root-knot and reniform nematodes tend to prefer sandy soils and soils with slightly higher clay or silt contents respectively (Monfort et al. 2007, Starr et al. 1993). It is very important to note that the total distribution of a nematode species and the areas where yield losses are observed can be quite different. Yield losses are generally observed only where coarser soil textures allow plants to enter moisture stress prior to other areas of the field.

In a survey of 1,249 South Carolina cotton fields approximately 47% of the fields were projected to sustain at least a !0% yield loss (Martin et al. 1994). At least 25% of the fields had Southern root-knot nematode present with 7% of the fields having levels that could cause at least a 10% yield loss. Reniform nematode was present in at least 12% of the fields with 3% of the fields having levels of reniform nematodes that could cause at least a 10% yield loss. Columbia lance nematodes were present in at least 61% of the fields sampled and in 37% of the fields levels of Columbia lance nematode were high enough to cause at least a 37% yield loss. Although nematodes were common in South Carolina cotton fields at least 33% of the fields did not need to be treated with a nematicide.

Yield losses due to plant-parasitic nematodes

The trend over the past 20 years has been for yield losses due to nematodes to increase (Koenning et al. 1999). Starr et al. 2007). In the 1950's yield losses due to nematode across the Cotton Belt were estimated at 1 to 2%. In 2000 losses due to nematodes in cotton were estimated to be over 4%. In 2004 plant-parasitic nematodes were estimated to cause a 4.68% reduction in cotton production in the United States (Blasingame and Patel 2005). Southern root-knot nematode was the most important species causing a 2.49% reduction and reniform nematode was estimated to cause a 1.93% reduction. Other nematodes such as sting and Columbia lance were estimated to cause the other 0.26% yield loss. In the Southeastern United States the percentage losses are even higher with losses in Georgia of closer to 8% (Table 1) and in South Carolina of over 7% (Table 2). Losses in North Carolina average right at 5% per year (Table 1). Southern root-knot nematode causes the most yield losses in the Southeast with losses of 6% in Georgia, 3% in North Carolina and 3.3% in South Carolina. In South Carolina yield losses due to Columbia lance nematode exceed 2% most years (Table 2).

Table 1. Nematode related % yield losses for Georgia and North Carolina for 2007 and 2008

	Georgia	Georgia	N. Carolina	N. Carolina
Species	2007	2008	2007	2008
Southern root-knot	6.0	6.0	3.0	3.0
Reniform	1.5	1.5	1.0	1.0
Columbia lance	0.5	0.5	1.0	1.0
Total	8.0	8.0	5.0	5.0

Data collated from Blasingame 2008 & 2009.

Dollar figures are hard to attach to these percentage yield losses due to the changing nature of cotton lint prices. However in South Carolina yield losses due to nematodes have averaged 7.3% for the last 3 years. In 2009 the total value of the cotton crop was $60 million. This would translate to a yield loss of over $4.4 million to nematodes just in South Carolina. Figures for Georgia and North Carolina would be even higher due to their much greater acreages.

Table 2. % yield losses attributed to nematodes for S. Carolina in 2008, 2009, and 2010.

Nematode species	2008	2009	2010
Southern root-knot	3.0	3.0	4.0
Reniform	1.5	1.5	2.0
Columbia lance	2.0	2.5	2.5
Total	6.5	7.0	8.5

Data collated from Blasingame 2009 and 2010 and Mueller personal observations.

Damage thresholds for cotton:

Nematode species vary greatly in their ability to cause yield losses (Dickerson et al. 2000). In addition the level of yield loss caused is usually a function of the interactions of nematode density, soil texture, and plant stress

(Koenning et al. 1996, Monfort et al. 2007). Although each nematode can cause damage as it feeds, to reach a 1evel of damage that can be detected often takes more than 100 nematodes in 100 ml of soil at planting to cause a measurable yield loss. In cotton or soybean this level is usually at least 10%. It is very difficult to visually detect before harvest differences in yield of less than 10%. As nematode densities increase, the levels of damage increase. This causes an increase in the level of economic inputs for nematicides or other control measures that the producer is willing to spend. Table 3 shows 2 different action thresholds for nematicide treatments in South Carolina. In fields that fall within the low threshold level damage due to nematodes can normally be controlled with a low rate of Temik® 15G or one of the seed treatments. In fields that fall within the high threshold level damage due to nematodes can only be controlled with the use of more efficacious and expensive, controls such as Telone® II or both at- plant and post-plant applications of a nematicide.

Table 3. Damage thresholds/100 ml soil for 4 species on cotton

Nematode species	Low threshold	High threshold
Root-knot	100	250
Reniform	250	625
Columbia lance	75	175
Sting	10	25

Crop Rotation as a Management Tool

Nematode species can vary substantially in their host ranges (Starr et al. 2007). Some species such as Southern root-knot nematode have a relatively wide host range that crosses numerous plant species and families. Other nematode species such as the soybean cyst nematode will infect and reproduce only on legumes. Even within a nematode genus individual species of nematodes can differ in host ranges. Southern root-knot nematode, *Meloidogyne incognita*, can reproduce on corn, cotton and soybean but not on peanut. However some races of Peanut root-knot nematode can reproduce on peanut but not on soybean. Table 4 shows the host status for the primary nematodes seen in rotations involving cotton in the Southeastern U.S. Cotton is a host for all of these species except Peanut root-knot nematode and soybean cyst nematode. Soybean is a host for all of these nematode species. Utilizing this chart it is easy to see that to reduce soybean cyst nematode a producer could grow any crop but soybean listed in the table. Reniform nematode densities can be controlled by growing corn or peanut. Southern root-knot or Columbia lance nematode populations can only be controlled by rotating to peanut.

Table 4. Host status of crops for six nematode species.

Nematode species	Corn	Cotton	Soybean	Peanut
Southern root-knot	Yes	Yes	Yes	No
Peanut root-knot	Yes	No	Yes	Yes
Reniform	No	Yes	Yes	No
Soybean cyst	No	No	Yes	No
Columbia lance	Yes	Yes	Yes	No
Sting	Yes	Yes	Yes	Yes
Lesion	Yes	Yes	Yes	Yes

Host Plant Resistance as a Management Tool

Host plant resistance is available as a management tool for some combinations of nematode species and host crops (Table 5). Remember that resistance is always for a specific nematode species and that resistance is not always present in all cultivars even within a company's product line. Soybean has the most resistance available among our common rotation crops (Table 5). There are soybean cultivars available with resistance to root-knot, soybean cyst, and reniform nematodes. However no resistance is available for Columbia lance nematode. Also most cultivars only have resistance to one of the three nematode species. There are currently no corn hybrids available with resistance to any of the common nematode species. However, resistance to Southern root-knot nematode does exist in some breeding lines. In cotton there are some cultivars which exhibit low to moderate levels of resistance to Southern root-knot nematode (Starr et al. 2002). This is often referred to as "tolerance" or "field tolerance" by the companies. However, all current levels of resistance in commercial cotton cultivars will respond to a nematicide, especially when nematode pressure is high. There are several excellent sources of resistance to root-knot and reniform nematodes currently under development in cotton breeding lines, however, none of them are ready to be released.

Table 5. Availability of host plant resistance to nematode species by crop.

Nematode species	Corn	Cotton	Soybean	Peanut
Southern root-knot	No	Limited	Yes	Non-host
Peanut root-knot	No	Non-host	Yes	limited
Soybean cyst	Non-host	Non-host	Yes	Non-host
Reniform	Non-host	No	Yes	Non-host
Columbia lance	No	No	No	Non-host
Sting	No	No	No	No
Lesion	No	No	No	No

Cultural Practices

Many different cultural practices have been used to try to limit the development of nematodes populations or to limit the amount of damage caused by nematodes. In the Coastal Plains of the Southeastern United States the one cultural practice that is consistently effective in limiting damage in cotton and soybean due to nematodes is deep tillage to break the hard pan. This can be a single shank in-furrow, turn plowing, or a paraplow. These will break the hard pan allowing the tap root to reach soil moisture and nutrients. In-furrow subsoiling or a paraplow have very little effect on the actual nematode population, they just minimize plant stress causing the nematode damage threshold levels to be higher (Hussey 1977). Several other cultural practices have been tried to control various nematode species. Destruction of cotton stalks and roots had only a minimal effect on Columbia lance nematode populations or yield in Georgia and North Carolina (Davis et al. 2000, Koenning et al. 2003). Many researchers have suggested early planting dates as a way to minimize damage from Columbia lance nematode but they have had limited success in demonstrating this in field trials (Koenning et al. 2003). The use of cover crops such as oats, rye or winter wheat will require monitoring of nematode populations present. They are non-hosts for reniform nematode but during warm winters could be a host and allow reproduction of Columbia lance and Southern root-knot nematode. Use of rye and winter wheat had no impact on Columbia lance nematode populations in Georgia (Davis et al. 2000). Reduced tillage operations have been a goal of many cotton producers to save fuel costs and conserve topsoil and organic matter. Table 5 shows that a strip till system differs in its effects on nematode populations according to the nematode species present. In this study in South Carolina (Mueller, unpublished data) strip tillage systems allowed reniform nematode populations to increase to a much greater extent than no-till or conventional tillage systems and that tillage effects on Southern root-knot nematode populations were much less pronounced.

Table 6. Effects of Tillage and Cultural Practices on recovery of nematodes from 100 ml soil

Tillage	Sample Date	Root-knot	Columbia lance	Reniform
Conventional	At plant	0	50	18
No-till	At-plant	49	71	39
Strip	At-plant	0	59	22
Conventional	Midseason	105	99	36
No-till	Midseason	141	71	19
Strip	Midseason	150	190	174

Using Nematicides

Temik® 15G has been the mainstay of cotton nematode control for over 35 years in most areas (Koenning et al. 2004) In the Southeastern United States only Telone® II at 3.0 gal./acre exceeds Temik® 15G in efficacy for control of cotton nematodes (Kinloch & Rich 1998, Noe 1990). However, Temik® 15G is used on many more acres since the standard rate of Telone II costs at least $33.00 per acre whereas 5.0 lbs/acre Temik 15G applied in-furrow at planting costs less than $15.00 per acre. For most growers the difference in price makes up for the lower level of control provided by Temik ®15G. Recently several seed treatment packages including one or more nematicides have been introduced into the cotton nematicide market. These include Aeris™ Seed-Applied Insecticide/Nematicide, Avicta® Complete Pak or Avicta® Duo Cotton and Poncho® Votivo™. As indicated on their labels these products are effective only against relatively low to moderate levels of nematodes. Zone management offers an effective way to manage nematodes while reducing grower costs and pesticide inputs. Growers typically apply a single rate of a nematicide across fields they are treating with nematicides. The development of precise yet cost effective soil texture maps using georeferenced soil electrical conductivity meters allows producers to predict where nematode-induced yield losses will occur and just as importantly where they will not occur. Nematicides can be applied using variable-rate site-specific application systems to make applications only where needed. In many instances the total amount of nematicide applied to a field and associated costs can be reduced by greater than 50% while nematode-induced losses are minimized (Monfort et al. 2007, Mueller et al. 2010).

Soil Sampling

In most states the percentage of fields where predictive nematode samples are taken in the Fall is relatively low, probably less than 5 to 10%. Without knowing what species of nematodes are present it is impossible to utilize the crop rotations as outlined in Table 4. Without know what level of pressure you have you cannot decide between the relatively cheap controls listed in the left column of Table 3 or the expensive right hand column. Taking predictive fall nematode samples is very cost effective. Most states charge $10 per sample or less. Even if you add an extra $1.00 per acre on for labor and associated costs you are investing at most $2.00 an acre to make a decision on spending no money on a nematicide versus $15 per acre or in the worst case scenario $35+ per acre. On many of our tests in South Carolina approximately 1/3 of a grower's fields do not have nematodes present at damaging levels. About 50% of the other fields typically require a low rate of nematicide and 50% require a high rate of nematicide. With knowledge of previous crops grown in a field you should be able to sample only those fields predicted to have high nematode levels, i.e. cotton planted after several years of corn or soybean. Cotton being planted after peanut should have a low probability of damaging nematode levels being present.

What is Needed for the Future

Unless a new, highly cost effective nematicide is developed which can minimize yield losses even when used in fields with high nematode densities we will need to combine management strategies to achieve the levels of control needed to maintain cotton production per acre at acceptable levels. We can anticipate the release of more cultivars at least partially resistant to southern root-knot nematode. These will require either the addition of a nematicide or will have to be grown in fields where crop rotations are maintaining nematode densities at low levels. Eventually cultivars with high enough levels of resistance to root-knot nematode may be released that can minimize losses even where southern root-knot nematode is present at high levels. These fields will need to be monitored for the development of races of southern root-knot nematode that could overcome the resistance. Eventually cultivars with acceptable levels of resistance to reniform will also be released and follow the same pattern of increasing resistance levels until they no longer need a boost from a nematicide. Crop rotation will become increasing important in reducing nematode densities. All of these strategies and combinations of strategies will rely heavily on fall sampling to monitor the species and densities of nematodes present in each field.

Summary

Bayer CropScience has entered into a voluntary agreement with EPA to phase out the use of Temik® 15G on cotton using the following timeline: 1). December 31, 2014 – the last date of sale by Bayer CropScience; 2). December 31, 2016 – the last date of sales by the distribution channel to the end user; and 3). August 31, 2018 – the last use date by an end user. This phase out of Temik® 15G use on cotton has brought renewed interest in what options are available for nematode management in cotton throughout the cotton belt. Temik® 15G provided a very cost effective level of control for most nematode species under a wide range of environmental conditions, cropping systems and levels of nematode pressure. Unless a new product is introduced we will be faced with the following scenario when Temik ®15G is no longer available:

Nematicides: Telone® II is currently still available and is a highly effective nematicide but is not as cost effective as Temik® 15G. Seed treatment nematicides are available and convenient to use, however they lack the ability to control higher levels of nematodes. Zone Management programs offer excellent opportunities to more effectively manage problem nematodes by utilizing site-specific applications of appropriate rates.

Host plant resistance: Nematode resistance in cotton is a developing option but currently only cultivars partially resistant to root-knot nematode are commercially available. Currently no commercial cultivars exhibit resistance to reniform nematode, but these cultivars are under development. Due to its migratory feeding habit we are not likely to develop cultivars resistant to Columbia lance nematode.

Crop rotations: Crop rotations are more of an option today than they have been in many areas due to enhanced commodity prices. Peanuts offer an excellent rotation option since the important nematode pathogens that go to peanut do not go to cotton. The reverse is also true in that the important nematode pathogens of cotton do not go to peanut.

Cultural practices: Use of a deep tillage to allow maximum tap root development will minimize plant stress and limit the damage nematodes can cause.

With the exception of Telone® II all of our current control measures provide only partial control of cotton nematodes. We will need to combine our available nematicides with rotation programs that keep nematodes at levels these nematicides can control. We will also need to deploy partially resistant and resistant cultivars as they are developed only into fields where the target nematode species is present at a manageable level.

The key to all effective control programs will be to manage each field individually. The density of each damaging species must be known for each field or in the case of zone management each area of a field. Once this is known effective rates of appropriate nematicides or resistant cultivars can be deployed. The key to all nematode management is to have each plant produce a healthy tap root of suitable length (usually 12 inches or longer) to obtain water and nutrients throughout the growing season. This requires nematode management primarily during the first 3 to 4 weeks of the growing season. The key to all effective nematode management requires knowledge of the species and density of nematodes present in each field. The only way to obtain this knowledge is through a nematode sampling program.

Acknowledgements

The author would like to thank Terry Kirkpatrick and Charles Overstreet for reviewing the presentation with him.

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