GROWTH HORMONE AND STARTER FERTILIZER EFFECTS ON ROOT-KNOT POPULATION SUPPRESSION AND COTTON YIELD ENHANCEMENT WHEN COMBINED WITH VELUM TOTAL OR VYDATE CLV Justin A. Luangkhot Kathy S. Lawrence Department of Entomology and Plant Pathology Auburn University, AL

Abstract

Field trials were conducted in Alabama to test the effects of adding plant hormones, starter fertilizers, and nematicides to *Gossypium hirsutum*, cultivar Fiber Max 1944 GLB2, in the presence of *Meloidogyne incognita*. Treatments for the trial included a water control, the nematicides Velum Total or Vydate CLV applied as an in-furrow spray, Ascend (plant growth hormones), Sure-K + Micro 500 (a starter fertilizer blend), and all possible combinations of the nematicides, hormones, and starter fertilizers. At 43 DAP all nematicide treatment combinations significantly reduced nematode populations by more than 70% compared to the untreated control. Overall Velum Total combinations had a larger reduction of nematode populations as compared to other treatments. The 63 DAP sampling period showed a similar trend with all nematicide combinations reducing nematode populations by 20% or greater compared to the untreated control. The Vydate CLV in-furrow spray with the addition of the starter fertilizer blend significantly reduced nematode populations at the second sampling period at 63 DAP. Seed cotton yields varied from 4412 to 5500 lb/A, in the untreated control and the Vydate CLV in-furrow spray respectively. Velum Total and Vydate CLV applied separately as in-furrow sprays both increased seed cotton yield by an average of 1000 lb/A over the control.

Introduction

The southern root-knot nematode (*Meloidogyne incognita*) is an economically important pest on crops because of the wide host range associated with the root-knot nematode. The cotton belt in the United States has shown incidence of *M. incognita* in every growing region (Walters, S. and Barker, K. 1994). In Alabama the southern root-knot nematode is typically found from the middle of the state down to the coast in the sandier soils. For the 2014 growing season in Alabama losses due to the southern root-knot nematode were estimated at \$85,000 (Lawrence *et al.* 2015.). Infected upland cotton plant symptoms are not easily discernable when compared to water or nutrient stress. Common symptoms exhibited are wilting, leaf reddening, stunting, and reduced boll set (Shepherd and Huck, 1989.). The main focus of this study was to reduce the economic losses due to southern root-knot nematode on upland cotton utilizing plant growth hormones, starter fertilizers, and nematicides. In this study the hypothesis was that with the addition of a nematicide as a protection agent for the cotton seedling in the earliest developmental stages that growth hormones and starter fertilizers could increase yields. Trials were conducted in multiple locations in Alabama during the 2015 growing season. There were two field locations in central Alabama which were naturally infested with southern root-knot and in microplot trials that provided simulated field conditions in a controlled setting for outside stresses on the campus of Auburn University.

Materials and Methods

Microplot Trial

Ten treatments were selected from earlier greenhouse trials for response of Fiber Max 1944 GLB2 to the addition of plant growth hormones, starter fertilizers, and nematicides. The trial was planted at Plant Sciences Research Center at Auburn University in a randomized complete block design using pot in pot containers. Kalmia loamy sand (80% sand, 10% silt, 10% clay) soil was used in the pots for the 2015 growing season. Treatments selected for the trial included 1) water control; 2) Velum Total (fluopyram 15.4% + imidacloprid 22.2%) 14 oz/A in-furrow spray (IFS); 3) Vydate CLV (oxamyl 42%) 17 oz/A IFS; 4) Velum Total 14 oz/A IFS + Ascend PGR (cytokinin 0.090%, gibberellic acid 0.03%, indole butyric acid 0.045%) 3 oz/cwt seed treatment (ST) + 3.2 oz/a IFS; 5) Vydate CLV 17 oz/A IFS + Ascend PGR 3 oz/cwt ST + 3.2 oz/a IFS; 6) Velum Total 14 oz/A IFS + Sure K (2-1-6) 1 gal/A IFS + Micro 500 (B 0.02%, Cu 0.25%, Fe 0.37%, Mn 1.2%, and Zn 1.8%) 1 qt/A IFS; 7) Vydate CLV 17 oz/A IFS + Sure K 1 gal/A IFS + Micro 500 1 qt/A IFS; 8) Velum Total 14 oz/A IFS + Ascend PGR 3 oz/cwt + 3.2 oz/a IFS; 8) Vydate CLV 17 oz/A IFS + Ascend PGR 3 oz/cwt + 3.2 oz/A IFS + Sure K 1 gal/A IFS + Micro 500 1 qt/A IFS; 9) Vydate CLV 17 oz/A IFS + Ascend PGR 3 oz/cwt + 3.2 oz/A IFS + Sure K 1 gal/A IFS + Micro 500 1 qt/A IFS; 9) Vydate CLV 17 oz/A IFS + Ascend PGR 3 oz/cwt + 3.2 oz/A IFS + Sure K 1 gal/A IFS + Micro 500 1 qt/A IFS; 9) Vydate CLV 17 oz/A IFS + Ascend PGR 3 oz/cwt + 3.2 oz/A IFS + Sure K 1 gal/A IFS + Micro 500 1 qt/A IFS; and 10) Velum Total 14 oz/A IFS + Hvydate CLV 17 oz/A IFS. Each pot had an artificially

established infested population of root-knot nematode plus the addition of half of stock inoculum pot added at planting. Populations included all stages of development of the southern root-knot nematode at planting. At 49 days after planting (DAP) shoot fresh weights, root fresh weights, and southern root-knot nematode populations were taken prior to the foliar spray. At 49 DAP shoot fresh weight and root fresh weights were combined and reported as biomass. Secondary sampling period was at 75 DAP to test the efficacy of the foliar spray application. Identical parameters were taken as the 49 DAP. The trials were allowed to run for the entire growing season until plots were harvested at 149 DAP. All data were analyzed in SAS 9.4 using PROC GLIMMIX procedure. The LS means were separated by Tukey-Kramer ($\alpha \le 0.1$).

<u>Field Trials</u>

The same ten treatments were evaluated during the 2015 growing season in true field conditions at the Plant Breeding Unit (PBU) in completely randomized block design. Soil type at PBU is a Kalmia loamy sand comprised of 80% sand, 10% silt, and 10% clay. Plots consisted of 4 rows, each 25 foot in length with 36-inch spacing between rows. All infurrow sprays were done using compressed air with flat fan LP 80001 spray tips at 5.75 gallons per acre. Parameters measured were sampled 43, 63, and 146 DAP. Parameters measured were shoot length, shoot fresh weight, root fresh weight, nematode populations, and yield per plot. At 43 DAP the shoot and root fresh weights were reported as biomass. Plants were randomly selected from each plot to measure data points at each sampling period. All data were analyzed in SAS 9.4 using PROC GLIMMIX procedure. The LS means were separated by Tukey-Kramer ($\alpha \le 0.1$).

The same ten treatments were evaluated during the 2015 growing season in true field conditions at the Prattville Agricultural Research Unit (PARU) in completely randomized block design. The soil at the PARU is a Lucedale sandy loam comprised of 64% sand, 10% silt, and 26% clay. Plots consisted of 4 rows, each 20 feet in length with 36-inch spacing between rows. All in-furrow sprays were done using compressed carbon dioxide with modified direct injected solid streams at 8.67 gallons per acre. Parameters measured were sampled at 31, 61, and 141 DAP. Measured parameters were shoot length, shoot fresh weight, root fresh weight, nematode populations, and yield per plot. At 31 DAP the shoot and root fresh weights were reported as biomass. Plants were randomly selected from each plot to measure data points at each sampling period. All data were analyzed in SAS 9.4 using PROC GLIMMIX procedure. The LS means were separated by Tukey-Kramer ($\alpha \le 0.1$).

Results

Microplot Trial

The addition of any starter fertilizer or hormone and the combinations treatments increased plant biomass compared to the control (Table 1). The addition of Velum Total, Ascend PGR, and starter fertilizer blend produced a significantly larger plant as compared to the Velum Total treatment alone. As compared to the control the Velum Total, Ascend PGR, and starter fertilizer blend significantly reduced the southern root-knot nematode eggs per gram of root as well. All Velum Total treatment combinations numerically reduced the reduced the southern root-knot populations as compared to the control.

After the foliar spray of the Ascend PGR and the Vydate CLV at pin head square or 6 to 8 leaf stage nematode samples were taken. Velum Total in-furrow spray with the addition of Ascend PGR seed treatment plus a foliar spray produced the largest plant biomass of all other treatments in the second sampling period (Table 1). Southern root-knot nematode population densities were similar between all treatments. The nematicide Velum Total in-furrow spray and the Vydate CLV foliar spray supported an average of 80 percent lower root-knot egg population as compared to the control. However these differences were not significant at the $P \le 0.1$ level. At harvest the largest numerical increase in grams per plot came from the addition of Velum Total in-furrow spray and the starter fertilizer blend at 312.2 grams of seed cotton.

Table 1. Plant biomass, root-knot numbers, and yields for Velum Total treatments for Microplot trial, 2015.								
		49 DAP		75 I	149 DAP			
Treatment	Rate/application	Biomass (g) ^z	Southern root- knot eggs/ gram of root	Biomass (g)	Southern root-knot eggs/ gram of root	Grams/plot		
Untreated		34.0 ab	814 a	112.8 a	481 a	225.5 a		
Velum Total	14 oz./acre IFS	22.0 b	66 ab	136.6 a	133 a	208.37 a		
Velum Total	14 oz./acre IFS							
Ascend ST	3 oz./cwt	43.6 ab	353 ab	158.6 a	102 a	164.0 a		
Ascend IFS	3.2 oz./acre							
Velum Total	14 oz./acre IFS							
Sure K	1 gal/acre	43.6 ab	511 ab	112.8 a	94 a	312.2 a		
Micro 500	1 qt./ acre							
Velum Total	14 oz./acre IFS							
Ascend ST	3 oz./cwt							
Ascend IFS	3.2 oz./acre	55.1 a	38 b	118.3 a	118 a	206.9 a		
Sure K	1 gal/acre							
Micro 500	1 qt./ acre							
Velum Total	14 oz./acre IFS							
Vydate CLV	17 oz./acre FS							
Ascend ST	3 oz./cwt	52 0 ab	305 ah	89.0.2	54 a	214.9 a		
Ascend IFS	3.2 oz./acre	52.0 db	505 d0	89.0 a	34 a	214.7 a		
Sure K	1 gal/acre							
Micro 500	1 qt./ acre							
^z Means followed by the same letter are not significantly different. ($\alpha \le 0.1$, Tukey-Kramer LS-means)								

The initial plant biomass taken at 49 DAP was similar between all treatments (Table 2). Vydate CLV in-furrow spray combined with Velum Total and Ascend ST+FS and Sure-K and Micro 500 IFS reduced southern root-knot nematode populations as compared to Vydate CLV in-furrow sprays with Ascend ST + FS and the Vydate CLV in-furrow spray plus Ascend ST + FS and Sure-K and Micro 500. The combination of Velum Total in-furrow at planting with Ascend PGR ST+ IFS, Sure-K and Micro 500 followed by the Vydate CLV foliar spray supported the lowest root-knot population.

During the second sampling period at 75 DAP, biomass measurements were again similar between all treatments. Ranking the treatments indicated Vydate CLV in-furrow spray with Ascend PGR produced largest biomass of all treatments (Table 2). In two treatment combinations, Vydate CLV plus Ascend ST + FS and the Velum Total infurrow spray, plus Vydate CLV foliar spray, Ascend ST + FS, plus starter fertilizer blend, sustained a significantly smaller southern root-knot population densities as measured by eggs per gram of root than the Vydate CLV in-furrow spray alone and the Vydate CLV in-furrow spray with starter fertilizer blend. Ranking the treatments found Velum Total in-furrow spray plus Vydate CLV foliar spray plus Ascend PGR, and starter fertilizer blend produced the largest grams per plot in comparison to all other Vydate CLV treatments. The total combination improved yields on average 28.0 grams per plot in compared to all other treatments. However, these increases in seed cotton were not at the $P \leq 0.1$ level.

1 doie 2. 1 lait 0	49 DAP 75 DAP					149 DAP
Treatment	Rate/application	Biomass (g) ^z	Southern root- knot eggs/ gram of root	Biomass (g)	Southern root-knot eggs/ gram of root	Grams/plot
Untreated		34.0 a	814 ab	112.8 a	481 abc	225.5 a
Vydate CLV	17 oz./acre IFS	38.8 a	411 ab	86.7 a	1269 a	170.0 a
Vydate CLV Ascend ST Ascend IFS	17 oz./acre IFS 3 oz./cwt 3.2 oz./acre	45.8 a	1599 a	194.3 a	73 c	203.2 a
Vydate CLV Sure K Micro 500	17 oz./acre IFS 1 gal/acre 1 qt./ acre	27.7 a	962 ab	127.8 a	488 ab	163.2 a
Vydate CLV Ascend ST Ascend IFS Sure K Micro 500	17 oz./acre IFS 3 oz./cwt 3.2 oz./acre 1 gal/acre 1 qt./ acre	35.4 a	1316 a	148.0 a	966 abc	172.7 a
Velum Total Vydate CLV Ascend ST Ascend IFS Sure K Micro 500	14 oz./acre IFS 17 oz./acre FS 3 oz./cwt 3.2 oz./acre 1 gal/acre 1 qt./ acre	52.0 a	305 b	89.0 a	54 c	214.9 a

Table 2. Plant biomass, root-kno	t numbers, and yields for Vydate	CLV treatments for Microplot t
	49 DAP	75 DAP
· · · · · · · · · · · · · · · · · · ·	~ .	Southern

Plant Breeding Unit

Forty-three days after planting there was no significant differences in biomass among the nematicide, starter fertilizer, and hormone treatments (Table 3). The Velum Total in-furrow spray alone or when combined with the Ascend growth hormones or Sure-K and Micro 500 starter fertilizers significantly reduced southern root-knot nematode population densities as compared to the control. The root knot population were reduced an average of 96% as compared to the untreated control.

During the sampling period taken at 63 DAP after the foliar spray of Ascend PGR and Vvdate CLV was applied, root fresh weights were recorded. All treatments were similar to control with the exception of the total combination of Velum Total plus Ascend ST +FS and Sure-K and Micro 500 starter fertilizers plus the Vydate CLV foliar spray which supported a smaller root system (Table 3). Southern root-knot eggs per gram of root were statistically similar between all the treatments as compared to the control. Yields were similar among all treatments and there were no significant differences in pounds per acre. Ranking the see cotton yields found Velum Total alone increase yield an average of 337 lb/A. Overall Velum Total- with or without Ascend PGR and starter fertilizers increased yield by 337 lb/A on average. Using the market value of \$0.63 per pound of seed cotton currently there is an increase of \$212.06 per acre.

Table 3. Plant biomass, root-knot numbers, and yields for Velum Total treatments for PBU trial, 2015.								
		49 DAP		63 DAP		146 DAP		
Treatment	Rate/application	Biomass (g) ^z	Southern root- knot eggs/ gram of root	Root fresh weight (g)	Southern root-knot eggs/ gram of root	lb/A		
Untreated		72.6 a	3641 a	21.4 a	307 a	1959 a		
Velum Total	14 oz./acre IFS	86.2 a	159 b	20.3 a	242 a	2368 a		
Velum Total	14 oz./acre IFS							
Ascend ST	3 oz./cwt	74.7 a	63 b	18.4 a	185 a	2200 a		
Ascend IFS	3.2 oz./acre							
Velum Total	14 oz./acre IFS							
Sure K	1 gal/acre	88.6 a	237 b	21.6 a	156 a	2303 a		
Micro 500	1 qt./ acre							
Velum Total	14 oz./acre IFS							
Ascend ST	3 oz./cwt							
Ascend IFS	3.2 oz./acre	83.9 a	110 b	19.8 a	212 a	2278 а		
Sure K	1 gal/acre							
Micro 500	1 qt./ acre							
Velum Total	14 oz./acre IFS							
Vydate CLV	17 oz./acre FS							
Ascend ST	3 oz./cwt	0472	180 b	175h	227 2	2320 2		
Ascend IFS	3.2 oz./acre)4.7 a	180 0	17.50	227 a	2329 a		
Sure K	1 gal/acre							
Micro 500	1 qt./ acre							
^z Means followed by the same letter are not significantly different. ($\alpha \le 0.1$, Tukey-Kramer LS-means)								

At the Plant Breeding Unit field plant biomass was similar between all treatments as compared to the control at the first sampling (Table 4). Vydate as in-furrow spray treatment alone or combined with Ascend ST + FS or Sure-K and Micro 500 and the Vydate + Velum Total + Ascend ST + FS + Sure-K and Micro 500 reduced southern root-knot nematode eggs per gram of root.

The second sampling at 63 DAP found the root system biomass was similar between all treatments (Table 4). Southern root-knot nematode eggs per gram of root were lower than the first sampling and were similar to the control. Treatments including a nematicide increased yields by 349 pounds per acre on average compared to the untreated control. The Vydate CLV in-furrow spray increased yields the most as compared to the control by 483 pounds per acre or \$304.29 per acre at \$0.63 per pound of seed cotton.

Table 4. Plant biomass, root-knot numbers, and yields for Vydate CLV treatments for PBU trial, 2015.								
	43 DAP			63 D	146 DAP			
Treatment	Rate/application	Biomass (g) ^z	Southern root- knot eggs/ gram of root	Root fresh weight (g)	Southern root-knot eggs/ gram of root	lb/A		
Untreated		72.6 a	3641 a	21.4 a	307 a	1959 a		
Vydate CLV	17 oz./acre IFS	90.5 a	572 b	25.1 a	196 a	2442 a		
Vydate CLV	17 oz./acre IFS							
Ascend ST	3 oz./cwt	104.7 a	228 b	23.1 a	278 a	2411 a		
Ascend IFS	3.2 oz./acre							
Vydate CLV	17 oz./acre IFS							
Sure K	1 gal/acre	93.8 a	349 b	21.0 a	91 a	2117 а		
Micro 500	1 qt./ acre							
Vydate CLV	17 oz./acre IFS							
Ascend ST	3 oz./cwt							
Ascend IFS	3.2 oz./acre	84.0 a	1388 ab	21.3 a	245 a	2242 a		
Sure K	1 gal/acre							
Micro 500	1 qt./ acre							
Velum Total	14 oz./acre IFS							
Vydate CLV	17 oz./acre FS							
Ascend ST	3 oz./cwt	04.7 a	180 b	1750	227 a	2329 a		
Ascend IFS	3.2 oz./acre)4.7 a		17.5 a				
Sure K	1 gal/acre							
Micro 500	1 qt./ acre							
^z Means followed by the same letter are not significantly different ($a \le 0.1$ Tukey-Kramer LS-means)								

Prattville Agricultural Research Unit

Plant biomass was again similar between all treatments at the Prattville Agriculture Research Unit at the 31 DAP first sampling (Table 5). The use of Velum Total in-furrow spray alone statistically reduced southern root-knot nematode populations as compared to the untreated control. The addition of the Ascend and or Sure-K + Micro 500 to the Velum Total increased the root-density similar to that of the control.

Root fresh weight taken at 61 DAP was similar between all treatments (Table 5). No differences were seen in southern root-knot nematode eggs per gram of root in all treatments at this second sampling either. Yields were also similar between all treatments.

Table 5. Plant biomass, root-knot numbers, and yields for Velum Total treatments for PARU, 2015.								
		31 DAP		61 DAP		141 DAP		
Treatment	Rate/application	Biomass (g) ^z	Southern root- knot eggs/ gram of root	Root fresh weight (g)	Southern root-knot eggs/ gram of root	lb/A		
Untreated		20.8 a	1307 a	31.1 a	76 a	3148 a		
Velum Total	14 oz./acre IFS	23.1 a	95 b	29.6 a	73 a	2791 a		
Velum Total Ascend ST Ascend IFS	14 oz./acre IFS 3 oz./cwt 3.2 oz./acre	20.7 a	314 ab	30.8 a	50 a	2858 a		
Velum Total Sure K Micro 500	14 oz./acre IFS 1 gal/acre 1 qt./ acre	24.1 a	1309 a	32.4 a	174 a	3084 a		
Velum Total Ascend ST Ascend IFS Sure K Micro 500	14 oz./acre IFS 3 oz./cwt 3.2 oz./acre 1 gal/acre 1 qt./ acre	21.7 a	358 ab	38.3 a	119 a	2974 a		
Velum Total Vydate CLV Ascend ST Ascend IFS Sure K Micro 500	14 oz./acre IFS 17 oz./acre FS 3 oz./cwt 3.2 oz./acre 1 gal/acre 1 qt./ acre	21.1 a	1309 a the different $(r < 0)$	37.4 a	81 a	2738 a		

Biomass was similar between all treatments at the first sampling 31 DAP (Table 6). Southern root-knot nematode eggs per gram of root were significantly reduced in the Vydate CLV in-furrow spray treatment alone compared to the untreated control. The Vydate +Ascend ST + FS and the Vydate + Sure-K +Micro 500 and the combination of Vydate + Ascend +Sure-K + Micro 500 reduced southern root-knot nematode eggs per gram of root similarly to the Vydate treatment alone but these combinations were not significantly different from the control.

Root fresh weight taken at 61 DAP was also similar between all treatments and the control (Table 6). No significant differences were seen for root-knot nematodes eggs per gram of root at this same time period. Yield was increased by 248 pounds per acre with Vydate in-furrow spray, Ascend PGR, and starter fertilizer blend as compared to all other Vydate CLV treatments.

Table 6. Plant biomass, root-knot numbers, and yields for Vydate CLV treatments for PARU, 2015.								
			31 DAP	61 1	DAP	141 DAP		
Treatment	Rate/application	Biomass (g) ^z	Southern root- knot eggs/ gram of root	Root fresh weight (g)	Southern root-knot eggs/ gram of root	lb/A		
Untreated		20.8 a	1307 a	31.1 a	76 a	3148 a		
Vydate CLV	17 oz./acre IFS	21.4 a	81 b	26.7 a	63 a	2689 a		
Vydate CLV Ascend ST Ascend IFS	17 oz./acre IFS 3 oz./cwt 3.2 oz./acre	24.1 a	174 ab	30.0 a	62 a	2683 a		
Vydate CLV Sure K Micro 500	17 oz./acre IFS 1 gal/acre 1 qt./ acre	19.4 a	161 ab	40.0 a	26 a	2671 a		
Vydate CLV Ascend ST Ascend IFS Sure K Micro 500	17 oz./acre IFS 3 oz./cwt 3.2 oz./acre 1 gal/acre 1 qt./ acre	20.8 a	191 ab	34.0 a	53 a	2939 a		
Velum Total Vydate CLV Ascend ST Ascend IFS Sure K Micro 500	14 oz./acre IFS 17 oz./acre FS 3 oz./cwt 3.2 oz./acre 1 gal/acre 1 qt./ acre	21.1 a	1309 a the different $(r < 0)$	37.4 a	81 a	2719 a		
means tonowe	u by the same letter a	tie not significant	iny uniformation ($\alpha \le 0$)	.1, 1ukey-Kfa	uner LS-means	s)		

Summary

The addition of a nematicide decreased southern root-knot nematodes eggs per gram of root in the earliest sampling period. The addition of the growth hormones provided by the product Ascend PGR showed a trend of increasing plant development with the addition to the seed and as a foliar spray. The starter fertilizer blend produced using Sure-K and Micro 500 showed an upward trend in most cases of increasing early biomass in the plants growth. Yields were increased in most instances when a nematicide with growth hormones and starter fertilizers were provided to the cotton plants at planting. No statistical differences were detected in any trials, but a trend was shown that the additions of the nematicides, growth hormones, and starter fertilizers increased yields as compared to the untreated control. Excessive variations in rainfall and drought during the months of July and August at both field locations, Plant Breeding Unit and Prattville Agricultural Research Unit, are speculated to have affected sampling of plants and nematodes. During the month of July, Plant Breeding Unit experienced 4.65 inches of rain early in the month followed by a long drought period (Alabama, 2015). During the same time period Prattville Agricultural Research Unit experienced 6.71 inches of rainfall early in the month followed by a long drought period (Alabama, 2015). Rainfalls in August for both Plant Breeding Unit and Prattville Agricultural Research Unit were experienced later in the month of August. Rainfall for these locations was 3.23 and 2.55 inches respectively (Alabama, 2015). These periods of heavy rainfall and drought could by a long drought period, and Prattville Agricultural Research Unit were experienced of heavy rainfall and drought could have eliminated the effects of the nematicides, growth hormones, and starter fertilizers.

References

Alabama Mesonet Weather Data, 2015. Agricultural Weather Information Service, Inc. Auburn, AL.

Lawrence, K., M. Olsen, T. Faske, R. Hutmacher, J. Muller, J. Mario, R. Kemerait, C. Overstreet, G. Sciumbato, G. Lawrence, S. Atwell, S. Thomas, S. Koenning, R. Boman, H. Young, J. Woodward, and H. Mehl. 2015. Cotton disease loss estimate committee report, 2014. Proceedings of the 2015 Beltwide Cotton Conference Vol. 1: 188-190 National Cotton Council of America, Memphis, TN. http://www.cotton.org/beltwide/proceedings.

Shephard, R.L. and M.G. Huck, 1989. Progression of root-knot nematode symptoms and infection on resistant and susceptible cottons. Journal of Nematology. Vol 21:235-241.

Walters, S.A. and K.R. Barker. 1994. Current distribution of five *Meloidogyne* species in the United States. Plant Disease Management Report Vol 78:772-774. American Phytopathological Society, St. Paul, MN.