VARIABLE RATE APPLICATION OF NEMATICIDES ON COTTON FIELDS: A PROMISING SITE-SPECIFIC MANAGEMENT STRATEGY

B. V. Ortiz
Agronomy and Soils Department
Auburn University
Auburn, Alabama

Calvin Perry
Biological & Agricultural Engineering Department
University of Georgia
Tifton, GA

Dana Sullivan
Turfsout
Tifton, GA

Robert Kemerait and Pamela Lu
Plant Pathology
University of Georgia
Tifton, GA

Richard Davis
USDA-ARS
Tifton, GA

Amanda Smith
Dept. of Agricultural and Applied Economics
University of Georgia
Tifton, GA

ABSTRACT

The impact of two nematicides [1,3 – Dichloropropene (Telone® II) and Aldicarb (Temik)] applied at two rates on RKN population density and cotton (*Gossypium hirsutum* L.) lint yield were compared across previously determined RKN management zones (MZ) in commercial fields between 2007 and 2009. The MZ were delineated using fuzzy clustering of various surrogate data for soil texture. All treatments were randomly allocated among blocks that spanned the entire length of the fields. Experimental sampling plots (16 rows by 100 feet long) including the four treatments were also randomly selected within each zone to collect RKN population density and yield. A consolidated analysis of RKN population by zone-treatment showed that regardless of the zone there were no differences between Temik rates or Telone® II rates. The result across zones showed that Telone® II provided better RKN control compared to Temik in high risk zones, comprised of more coarse-textured, sandy soil. However, in low risk zones, which were comprised of relatively heavier textured soil compared to the

high risk areas, the application of ant of the treatments provided sufficient control to maintain RKN populations below the recommended threshold (100 juveniles 100 cc^{-1}) . In these zones, a farmer would lose money if a high rate of Telone® II is applied. The results from this study clearly showed that RKN control and final yield varied with respect to the nematicide type and rate across management zones (MZ). These results are promising and support the idea of variable rate nematicide applications based on RKN risk zones.

INTRODUCTION

Southern root-knot nematode [*Meloidogyne incognita* (Kofoid & White) Chitwood] (RKN) is considered the most harmful plant-parasitic nematode for cotton production in the U. S. A. In Georgia, the third largest upland cotton producer in the U. S. A., estimated losses attributed to nematodes in 2007 totaled $50.2 million dollars with RKN contributing to 75% of those losses. A survey carried out between 2002 and 2003 showed that major cotton-producing counties in Georgia had RKN population densities above the critical management threshold (100 second juveniles of RKN per 100 cm^3 of soil), indicating that cotton producers lost about 77,000 bales of cotton annually from RKN damage (Blasingame and Patel, 2001; Kemerait et al., 2004).

The management of RKN in the southern U. S. has been characterized mainly by crop rotation in which the host plant, cotton, is replaced by a non-host or poor-host plant. In addition, the use of soil fumigants such as Telone® II (1,3 – Dichloropropene) or Aldicarb (Temik), which are usually applied at uniform rates to control population density, has become a common practice for cotton growers. However, the high cost of these nematicides suggests there may be an advantage for site specific nematicide applications. Therefore, a management zone approach targeting areas at risk for high nematode populations can support application of nematicides, as well as improve placement and efficacy compared to uniform field application strategies.

Root knot nematodes exhibit an aggregated pattern of spatial variability, influenced primarily by variability in soil texture. This behavior suggests that site-specific management (SSM) of nematicides may be used to improve the efficacy of nematicide control and reduce costs. Studies conducted in Louisiana have shown differences in average nematode population and cotton yield with respect to the application of different nematicides treatments as a function of soil texture (Erwin et al., 2007; Wolcott, 2007). When evaluating the differences in yield between Telone® II and non-Telone® II treatments applied across two fields in Louisiana, coarsely textured areas in one of the fields showed a greater response to the application of Telone® II compared to areas having a relatively heavier soil texture (Erwin et al., 2007). Although the fields planted with cotton in Georgia do not exhibit abrupt changes in soil texture, differences in soil texture are mainly due to variability in sand particle size.

The objectives of this study were to: 1) compare the impact of type and rate of nematicide on RKN populations and cotton lint yield across RKN management and 2) determine the profitability of using different rates of nematicides according to a within-field RKN risk level.

MATERIALS AND METHODS

Study field and experimental plan

Differences between nematicides and nematicide rates across RKN management zones were evaluated on two fields (20-23 ha) located in an intensely row-cropped region of southern Georgia, USA. One of the tests was conducted at the CC field in 2007. The others were conducted in 2008 and 2009 at the WHE field. The fields were planted with the Delta & Pineland (DPL) 555 Boll-Guard®, Round-Up-Ready® cotton (*Gossypium hirsutum* L.) variety, using a 4 row Monosem vacuum planter. Planting occurred approximately 2 weeks after each field was strip-tilled.

Management zones (MZ) for RKN were delineated according to the methodology developed by Ortiz (2008) which is based on fuzzy clustering of various surrogate data for soil texture The surrogate data for soil texture included in the MZ delineation were: terrain elevation and slope, normalized difference vegetation index (NDVI) calculated from bare soil spectral reflectance, and apparent soil electrical conductivity (EC_a). A VERIS® 3100 implement (Veris Technologies, Salina, Kansas, USA) was used to collect EC_a at two soil depths: 0 - 30 cm (shallow, $EC_{a\text{-shallow}}$) and 0 - 90 cm (deep, $EC_{a\text{-deep}}$). Characteristics of the RKN management zones respect to soil EC_a and elevation for the two fields included in this study are shown in Table 1. Ortiz et al. (2010) showed that $EC_{a\text{-deep}}$ can be used to delineate areas with different levels of risk (probability) for having RKN population above the threshold used in Georgia for commercial application of nematicides. Ortiz (2008) also showed that areas/zones with low population of RKN are associated with high mean values of EC_a contrasting with high RKN population present on areas/zones with low mean values of EC_a.

Each experiment was established in a randomized complete block design with four treatments randomly allocated in strips of 16 rows, spanning the length of the field. The treatments were replicated four to six times according to the size of the zone. Sampling plots in the middle of each strip (4 rows by 100 feet long) were randomly identified within each MZ. The two nematicides evaluated were Temik (Aldicab) and Telone® II (1,3 Dichloropropene) and the nematicide rates included: Temik – 3.4 Kg/ha (T1), Temik – 6.7 Kg/ha (T2), Telone® II– 7.4 gal/ha plus Temik 3.4 Kg/ha (T3), and Telone® II– 14.8 gal/ha plus Temik 3.4 Kg/ha (T4). Between each set of 16 rows of treatments a strip of four rows was left as a buffer which received 3.4 Kg/ha Temik. This rate was applied in the buffer as the cooperating farmers required, at a minimum, an insecticide rate of Temik in all rows.

Table 1. Characteristics of the RKN management zones respect to soil EC_a and elevation. CC and WHE fields.

Field ID	Zone ID	$EC_{a\text{-shallow}}$ (mS/m)		$EC_{a\text{-deep}}$ (mS/m)		Elevation (m)	
		Mean	CV	Mean	CV	Mean	CV
CC	1	1.0	39.6	1.5	38.8	250.0	1.1
	2	2.2	120.6	2.5	87.0	256.9	1.7
	3	0.6	20.0	0.7	29.3	260.5	0.8
WHE	1	2.85	20.3	4.8	42.3	105.3	0.7
	2	2.5	22	3.0	34.3	107.5	0.6

Data collection

Composite soil samples for nematode population determination were collected from each experimental unit three times during 2007 and four times during the 2008 and 2009 growing seasons. Samples were collected from a depth of 16-30 cm using a soil probe with a 3 cm diameter opening and approximately 20 cm. Second-stage juveniles were extracted from 100 cm^3 of soil by centrifugal flotation (Jenkins, 1964). Cotton was harvested using an Ag Leader cotton yield monitor system (Ag Leader Technology, Ames, IA) installed on a 9965 four-row John Deere picker. The system used an AgGPS 132 DGPS receiver with differential correction to calculate the position of the harvester at any time in the field. Nematode treatment effects on nematode population and yield and the interaction between treatments and zones on RKN population density were computed through PROC MIXED in SAS (SAS Institute, 2007).

RESULTS

Impact of nematodes and nematicide rates on nematode population

The criteria for determining the best management option (nematicide type and rate) by RKN management zone was based on nematode population and yield differences ($P<=0.05$). The analysis of average season nematode population showed that for all three tests, the highest reduction on nematode population occurred on the zone 3 (CC field) and zone 2 (WHE field) using the high rate of Telone® II (T4) compared to the control treatment (T1) (Table 2). These two zones (3-CC field and 2-WHE field) were characterized by having the lowest mean values of $EC_{a\text{-shallow}}$ and $EC_{a\text{-deep}}$. Ortiz et. al (2010) and Ortiz et. al (2008) using data collected from 11 cotton fields showed a negative spatial correlation between RKN and $EC_{a\text{-}deep}$ which indicate that high population of RKN can be found on areas with low $EC_{a\text{-}deep}$ values usually related to sandy soil areas (Khalilian et al., 2001; Monfort et al., 2007).

Table 2. Average RKN population density differences between nematicide treatments applied across the RKN management zones

Field ID	Zone ID	Nematicide treatments† T1	T2	T3	T4
		RKN population (second stage juveniles/100 cm^3 of soil)‡			
CC	1	77.9a	101.6a	64.0a	43.3a
	2	102.8ab	152.8a	57.3b	44.7b
	3	173.7ab	195.4a	90.3ab	57.3b
WHE08	1	152.9a	84.25a	86.5a	70.4a
	2	81.95ab	105.3a	47.75bc	26.75c
WHE09	1	432.75a	246.25b	112.67b	127.75b
	2	275.67ab	394.16a	202.67ab	101.17b

† T1: Temik 3.4 Kg/ha, T2: Temik 6.7 Kg/ha, T3: Telone® II 7.4 gal/ha + Temik 3.4 Kg/ha, T4: Telone® II 14.8 gal/ha + Temik 3.4 Kg/ha.
‡Means in a row followed by the same letter are not significantly different ($P<=0.05$) according to LSD

For the CC field – Zone 1 (low-risk), even though there were not significant differences in RKN population between the treatments, a numerical difference in RKN population was observed between Temik at 6.7 Kg/ha (T2) and Telone® II at 14.8 gal/ha plus Temik at 3.4 Kg/ha (T4) (Table 2). Considering the low risk for high population of RKN within zone 1 along with the lack of significant treatment differences, data suggest that any nematicide applied there had a low impact on RKN population; therefore a low rate of Temik may be sufficient nematicide control within this zone. In zone 2, there were significant differences between treatments ($P < 0.05$), especially between nematicides (Temik and Telone, 60 % reduction using Telone). On average, a reduction in RKN population density was observed between treatments: T4 vs. T1 (56% reduction), T3 vs. T2 (62% reduction), T4 vs. T2 (71% reduction). In zone 3, nematicide differences were also observed (60% RKN reduction using Telone® II compared with Temik). The differences on RKN population between rates were very similar to zone two, T4 vs. T1 (67% reduction), T3 vs. T2 (54% reduction), T4 vs. T2 (70% reduction). A significant reduction in RKN population between Telone® II and Temik treatments (T3T4 vs. T1T2) when we moved across the management zones was observed. In zone 1, the lowest reduction in average RKN population was observed in Telone® II treatments over Temik treatments, 36 second stage juveniles/100 cm3 of soil which corresponded to 40% reduction. In contrast, zone 3 exhibited the highest reduction in average RKN population when using Telone® II compared to Temik. The reduction was 60% which was equivalent to 111 second stage juveniles/100 cm^3 less on average in the plots receiving any of the Telone® II treatments. A consolidated analysis of the RKN population density by zone-treatment showed that no matter the zone there were no differences between Temik rates (T1 and T2 treatments) or Telone® II rates (T3 and T4 treatments).

For the WHE08 field – Zone 1 (low risk), no significant differences between nematicides and nematicide rates were observed (Table 2). RKN population was similar for most of the treatments. In contrast, there were significant differences between nematicides and rates on zone 2 (high risk). The best control, lowest RKN population, was obtained when Telone® II was applied at the rate of 14.8 gal/ha . Telone® II provided with a 60% reduction on RKN population respect to Temik. On average, a reduction in RKN population was observed between treatments: T4 vs. T1 (67% reduction), T3 vs. T2 (54% reduction), T4 vs. T2 (74% reduction).

For the WHE09 field – Zone 1 (low risk), even though there were not significant differences in RKN population between most the treatments, a numerical difference in RKN population was observed between the nematicides. RKN population was reduced 49% when Telone® II was applied instead of Temik (Table 2). On average, a reduction in RKN population density was observed between treatments: T4 vs. T1 (70% reduction), T3 vs. T2 (54% reduction), T4 vs. T2 (48% reduction). In zone 2, Telone® II provided with a 55% RKN population control respect to Temik. The highest reduction on RKN population was observed when the high rate of Telone® II (T4) was compared with the high rate of Temik (T2), 74% reduction with T4. When other treatments were compared, reductions in RKN population were also observed: T4 vs. T1 (63% reduction) and T3 vs. T2 (49% reduction).

Impact of nematodes and nematicide rates on cotton yield

For the CC field, significant yield differences between MZ, treatments and most important an interaction between MZ and treatments was observed (Table 3). In zone 1, the zone with the lowest RKN population, there was a significant difference ($P < 0.05$) in yield between treatments. The highest difference in yield, 245.5 Kg/ha, between treatments was found when comparing T4 with T2. However, the average difference in RKN population between these treatments was not significant, peaking at 58 second stage juveniles/100 cm3 of soil. When the average yield from Temik (T1 and T2) and Telone® II (T3 and T4) treatments was compared, an increase of 137 Kg/ha was observed, a 12% yield increase for Telone® II treatments. This result is contrasting with the RKN population where not significant differences in between the nematicides Temik and Telone® II was observed. On average, significant differences in yield of 120 Kg/ha were observed when comparing T4 vs T1, T3 vs T2, and T4 vs T3. In zone 2, significant differences in yield between the nematicides (Temik vs. Telone) were observed with an increment of 191 Kg/ha (28% increase) on the plots receiving Telone. There were also differences between nematicide rates with the highest yield increments occurred with the high rate of Telone® II (T4) compared with the low and high rates of Temik (T1 and T2). The greatest yield increment was observed comparing treatments T4 and T2, 266 Kg/ha. This yield response was expected due to the 71% reduction in RKN population caused by the application of high rate of Telone® II (T4) compared to high rate of Temik (T2). In zone 3, the zone with the highest RKN population, there were significant differences between nematicides, 124 Kg/ha increment on Telone® II plots over Temik plots. This result could be associated with the 60% reduction in RKN population due to Telone® II application compared with Temik within this zone. In contrast, there were no significant differences between Temik rates (T1 and T2 treatments) or Telone® II rates (T3 and T4 treatments), Table 3.

The similarities in average RKN population between zones 2 and 3 and the contrasting yield between these two zones suggests that RKN population is not the only factor reducing and/or limiting cotton yield. The presence of high RKN population density in zones with low water availability, coarse-textured sandy areas with lowest $EC_{a\text{-deep}}$ values, may exacerbate yield losses. Ortiz et al. (2007) evaluating the relationship between cotton yield, soil physical and chemical properties, and RKN in two cotton fields found the presence of aggregated high population densities of RKN in coarse textured areas exacerbate yield losses due to the conjunction of low uptake of water and K by RKN infected plants and the low availability of these resources in sandy areas. Even though the RKN population density between the three treatments were similar, yield losses increased when RKN were present in coarse-textured sandy areas like zone 3. Therefore, variable or precision application of the appropriate rate and type of nematicide may reduce cost, increase nematicide efficacy and improve economic returns on nematicide inputs.

For the WHE08 field, yield differences respect to the nematicide treatments were not significant in zone 1, however differences were observed in zone 2. Although the differences between nematicides were not significant ($P<0.13$), an increment of 176 Kg/ha was observed on plot receiving Telone® II compared to the Temik plots.   In addition, there were no significant differences between Temik rates (T1 and T2 treatments) or Telone® II rates (T3 and T4 treatments), Table 3. This result could be associated with similarities in RKN population between nematicides and nematicide rates (Table 2). In zone 2, the highest yield was obtained from plots receiving the high rate of Telone® II (T4) which exhibited the better control of RKN population, the lowest average RKN population compared to the other treatments. Numerical yield differences among nematicide rates ranged from 11 to 260 Kg/ha. The highest yield differences resulted from comparing the high rate of Telone® II (T4) with the low rate of Telone® II (T3) and high rate of Temik (T2) with increments of 260 Kg/ha and 137 Kg/ha, respectively.

For the WHE09 field, there were not significant differences in yield respect to the treatments for both zones (Table 3). Similar yield was observed by zone and treatment by zone. The high yield observed in this field respect to the 2008 growing season and the small differences between nematicides and rates could be explained by the high number of rainy days occurred in the 2009. For the months of May, July, August, September and October, the number of rainy days exceed 6, 2, 6, 6,and 10 days respectively. This frequency of rain could reduce the impact of any plant water stress that nematode parasitism in the roots might cause. Therefore, the low yield differences between treatments that were observed.

Table 3. Influence of nematicide treatments on cotton yield across the RKN management zones.

Field ID	Zone ID	Nematicide treatments†			
		T1	T2	T3	T4
		Lint (Kg/ha)			
CC07	1	1078.5b	974.3c	1105.7ab	1219.9a
	2	696.9b	678.2b	817.9a	940.1a
	3	334.6d	387.1c	585.9b	646.9a
WHE08	1	1088.7a	1168.7a	1237.0a	1196.9a
	2	1073.1ab	1061.4ab	937.6b	1198.6a
WHE09	1	1383.4a	1370.5a	1395.8a	1222.1a
	2	1417.0a	1350.0a	1333.5a	1298.5a

† T1: Temik 3.4 Kg/ha, T2: Temik 6.7 Kg/ha, T3: Telone® II 7.4 gal/ha + Temik 3.4 Kg/ha, T4: Telone® II 14.8 gal/ha + Temik 3.4 Kg/ha.
‡Means in a row followed by the same letter are not significantly different (P<=0.05) according to LSD

Economic analysis

For the CC field, considering differences in RKN population and yield across zones, only significant differences in revenue with respect to the nematicide rates occurred within the higher risk zones. Therefore, the application of Telone® II (at any rate) was economically prudent in zones 2 and 3 (Table 4). For zone 3, when Telone® IIrates were compared, similar revenue was reached either the low or high rate of Telone. Contrasting with it, in zone 1 with the lowest RKN population, the cost of Telone® IIor higher rate of Temik application would not be offset by yield. In the lower risk zone (zone 1) the farmer would have actually lost money ($1368- $1338) when using Telone 7.4 gal/ha rather than the base Temik 3 lb/acre, treatment. He would have realized a small gain ($1388- $1368) by increasing rate to 14.8 gal/ha .

At the WHE field – 2008 season, the zone 1 did not exhibited significant differences on revenue between the treatments. Base on the small differences in RKN population and yield observed in this zone, the farmer would have actually lost money ($1392- $1550) when using Telone, 14.8 gal/ha rather than the base Temik, 6.7 Kg/ha , treatment. The best options for this low risk zone were the high rate of Temik (T2) or the low rate of Telone® II (T3) both with the same revenue ($1550). For zone 2, a zone with higher RKN risk based on field attributes especially $EC_{a\text{-}deep}$ data (lowest values), a better control of RKN population and higher yield was observed when the high rate of Telone® II(T4) was applied which resulted in a similar revenue to the Temik treatments with lower RKN control ($1394, $1442, $1403 for T4, T1 and T2 respectively).

At the WHE field – 2009 season, no differences in revenue were observed between the zones and treatments by zone. This could be explained by the small differences in yield observed in 2009. Therefore, if a weather forecast for the cotton growing season at this location indicates frequent rains and/or excess or precipitation above average, the farmer may chose to apply Temik, at any rate, to control RKN population instead of using Telone. There results might agree with data from studies conducted in the Mississippi Delta river area of Louisiana which demonstrated that a yield increase of 90-112 Kg/ha was necessary to cover the cost of nematicide treatments such as Telone® II (Erwin et al., 2007).

Table 4. Average revenue by zone and treatment.

Field	Zone	Revenue †	Nematicide Treatment‡			
			T1	T2	T3	T4
CC	1	(US$/ha)	1368	1201	1338	1388
		C.V. (%)	6.8	12.2	8.5	14.5
	2	(US$/ha)	893	841	993	1021
		C.V. (%)	32.8	36.5	28.5	30.7
	3	(US$/ha)	373	429	642	617
		C.V. (%)	39.1	18.5	12.2	17.8
WHE08	1	(US$/ha)	1464	1550	1550	1392
		C.V. (%)	2.7	10.7	15.0	4.6
	2	(US$/ha)	1442	1403	1141	1394
		C.V. (%)	8.6	10.6	18.9	14.5
WHE09	1	(US$/ha)	1867	1825	1767	1426
		C.V. (%)	9.4	1.7	3.5	4.4
	2	(US$/ha)	1912	1797	1682	1531
		C.V. (%)	5.1	2.6	6.8	7.9

† Revenue adjusted for marketing and treatment costs
‡ T1: Temik 3.4 Kg/ha, T2: Temik 6.7 Kg/ha, T3: Telone® II 7.4 gal/ha + Temik 3.4 Kg/ha, T4: Telone® II 14.8 gal/ha + Temik 3.4 Kg/ha.

CONCLUSIONS

The results from the analysis of data for two fields, three different growing seasons, included in this study clearly showed that RKN control and final yield varied with respect to the nematicide type and rate across risk management zones. A consolidated analysis of the RKN population density by zone-treatment showed that regardless of the zone there were no differences between Temik rates (T1 and T2 treatments) or Telone® IIrates (T3 and T4 treatments). For most of the fields and seasons, there were not significant differences between the nematicide rates respect to RKN population and and yield in the zone with the lowest $EC_{a\text{-shallow}}$ and $EC_{a\text{-deep}}$ average values (low risk zone). Under these conditions, a high rate of Telone® IIwill not be the most economical option for a farmer. Therefore, the application of Temik would be enough to control RKN present in the lower risk zones.

In contrast, the zone with the lowest $EC_{a\text{-shallow}}$ and $EC_{a\text{-deep}}$ average values, the high risk zone exhibited a better control of the RKN population by the nematicides and differences between the rates were observed. The highest reduction in average RKN population was observed with the use of Telone. Similarly to the RKN population, yield differences between nematicides and rates were observed. The high yield and better RKN control observed on the plots receiving the high rate of Telone® II(T4) resulted in similar revenue compared to the plots receiving Temik or the low rate of Telone® II(T3). However, plots receiving Temik or low rate of Telone® II(T3) did not provide as good control as high rate of Telone® IIwhich result in the best option for the farmer (RKN control and high yield).

In conclusion, the results presented here demonstrate the value of variable rate application of nematicide based on management zones depicting different levels of risk for high population of RKN.

REFERENCES

Blasingame, D. and Patel, and M. V. 2001. Cotton disease loss estimate committee report. In *Proc. 2001 Beltwide Cotton Conference*. Anaheim, CA.: National Cotton Council.

Erwin, T., R. Letlow, C. Overstreet, and M. Wolcott. 2007. Nematode Management of Cotton in Morehouse Parish, Louisiana. In *Beltwide Cotton Conference*. New Orleans.

Kemerait, R. C., R. F. Davis, P. H. Jost, C. L. Brewer, S. N. Brown, B. Mitchell, W. E. Harrison, R. Joyce, and E. McGriff. 2004. Assessment of nematicides for management of the southern root-knot nematode, Meloidogyne incognita, in Georgia. Tifton, GA. *In* 2004 Georgia cotton research and extension reports.: The University of Georgia. Available at: http://commodities.caes.uga.edu/fieldcrops/cotton/rerpubs/2004/p202.pdf.

Khalilian, A., J. D. Mueller, S. C. Blackville, Y. J. Han, and F. J. Wolak. 2001. Predicting cotton nematodes distribution utilizing soil electrical conductivity. In. *Proc. 2001 Beltwide Cotton Conference*. Memphis, TN.: National Cotton Council.

Monfort, W.S., T.L. Kirkpatrick, C.S. Rothrock, and A. Mauromoustakos. 2007. Potential for site-specific management of meloidogyne incognita in cotton using soil textural zones. *J. Nematol.* 39: 1-8.

Ortiz, B. V., D. G. Sullivan, C. Perry, R. F. Davis, G. Vellidis. 2007. Integrated effects of root-knot nematode, fertility, and landscape features on cotton yield response. In *Proc. of World Cotton Research Conference*. Lubbock, Texas. 10-14 Sep. 2007. (peer review paper).

Ortiz, B.V. 2008. Study of the spatial variability of the Southern Root-Knot Nematode (Meloidogyne Incognita) and its impact on cotton yield. Ph.D Dissertation. Biological and Agricultural Engineering Department, The University of Georgia , Georgia, GA.

Ortiz, B.V., C. Perry, P. Goovaerst, G. Vellidis, and D. Sullivan. 2010. Geostatistical modeling of the spatial variability and risk areas of southern root-knot nematodes in relation to soil properties. Geoderma 156:243-252.

Jenkins, W. R. 1964. A rapid centrifugal flotation technique for separating nematodes from soil. *Plant Disease* 48: 692.

SAS Institute Inc. 2007. SAS Online Doc (R) 9. 1. 3. Cary, NC: SAS Institute Inc.