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Root-Knot Nematode Effect on Nine Cotton Cultivars in Mississippi[1]

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ABSTRACT

Lint yields of cotton (*Gossypium hirsutum* L.) in the USA have decreased since the mid-1960s even though new cultivars developed during this period are more productive than the cultivars they replaced. Nematodes have been suspected of being a factor in declining yields. This field study was designed to compare the performance of nine cotton cultivars when grown in fumigated and nonfumigated soils (Typic Dystrochrepts). The target nematode species was the root-knot nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood, and the fumigant was 92% 1,3-dichloropropene (Telone II[3]). Seedling survival and plant height were not affected significantly by soil fumigation. Numbers of second stage root-knot nematode juveniles in soil samples and root-gall indices of cotton cultivars were reduced by fumigation with Telone II. The greatest reduction in root galling occurred on nematode-susceptible cultivars. Telone II reduced lint yield of 'Delcot 311', 'Auburn 56', and LA 434 RKR from 1 to 4%. The latter two are the most tolerant to root-knot nematode of the cottons tested. Lint yields of the more susceptible cultivars were increased from 2 to 6% by Telone II. Regression analysis of the yield differences between nonfumigated and fumigated treatments on the root-knot indices of the cultivars grown in the nonfumigated plots showed that *M. incognita* reduced lint yields 35.7 kg ha^{-1} for each unit increase in root-gall index.

***Additional index words:* *Meloidogyne incognita*, Plant stand, Plant height, Root-gall index. Yield, Nematicide, *Gossypium hirsutum* L.**

THE ROOT-KNOT NEMATODE , *Meloidogyne incognita* (Kofoid & White) Chitwood, was first described on cotton (*Gossypium hirsutum* L.) in Alabama in 1982, and is one of the most destructive pests of cotton. Losses to root-knot nematode occur in all cotton production areas of the world, but the magnitude of loss has not been quantified in many areas. Since the mid-1960s, cotton yields in the USA have declined (3). Many factors, including nematodes, have been suspected to cause yield decline, but the actual causes have not been determined.

Root-knot nematode not only debilitates cotton plants, but may also predispose the plants to invasion by other pathogens, which may result in disease complexes. Losses from disease complexes usually exceed that caused by each individual organism. In recent studies, cotton yields in western Texas were increased > 25% by nematicides used to control root-knot nematode in fields where fungus-nematode disease complexes were not evident (4, 5, 6). In the Mississippi River Delta, the root-knot nematode is widespread and may affect yield of cotton in sandy soils, primarily in fields where Fusarium wilt caused by *Fusarium oxysporum* f. sp. *vasinfectum* (Atk.) Snyd. & Hans. is not evident. The effects of this nematode on cotton production have not been quantified in the Delta, but we have observed severe galling on cotton roots (unpublished), which suggests that root-knot nematode may affect the development, fruiting, and yield of cotton in many fields in the Delta.

The objective of our study was to determine the effects of preplant application of 92% 1,3-dichloropropene (Telone II) on nematode control, plant stand, plant height, lint yield, and root-gall index of nine cotton cultivars that ranged from moderately resistant to susceptible to *M. incognita*.

MATERIALS AND METHODS

The experiment was conducted from 1980 to 1982 in a Beulah fine sandy loam soil (coarse-loamy, mixed, thermic Typic Dystrochrepts) at Stoneville, MS. The test was conducted in a field where small plots of cotton cultivars and breeding lines had been planted annually for 40 yr or longer. Cottons that ranged from highly susceptible to resistant to *M. incognita* and other diseases had been grown randomly in designated plots in the field. During this period, most of the cultivars that were grown were susceptible to soil-borne organisms, which should have helped to maintain inoculum of pathogens. Severe galling caused by *M. incognita* occurred on the roots of cotton plants grown in the field, but Fusarium wilt was not evident. Since the mid-1960s, lint yields have

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declined in this field, but the cause of the yield decline has not been determined (3).

Land preparation in autumn of each year consisted of shredding cotton stalks, disking, and subsoiling. In late winter or early spring, trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*,-dipropyl-*p*-toluidine) was applied broadcast at 1.1 kg a.i. ha^{-1}, incorporated, and the soil was bedded. Immediately before planting, the beds were about 80 mm high following cultivation with a bed shaper. Anhydrous ammonia at 101 kg N ha^{-1} was applied preplant annually. Fluometuron [1,1-dimethyl-3-(α,α,α-trifluro-*m*-tolyl) urea] at 1.1 kg a.i. ha^{-1} was applied in a 250 mm wide band over the row after planting.

Telone II at 86 kg a.i. ha^{-1} was applied through a single shank per row 250 mm below the top of the seedbed 14 days or longer before planting. A drag on the applicator sealed and firmed the soil following injection of Telone II.

Nine cotton cultivars developed over a wide area of the southern USA were evaluated. Their levels of resistance to *M. incognita* were: 'Auburn 56' and breeding line LA 434 RKR, moderately resistant; 'Delcot 311', 'DES 56', 'CAMD-E', 'Deltapine 41', 'Stoneville 825', 'Coker 201', and M-8, a double haploid, susceptible.

Seed of the cultivars tested were obtained from boll samples harvested from a common test the previous year. These high quality seeds were acid-delinted and then coated with the fungicides PCNB + ETMT L-21 [22.8% pentachloronitrobenzene + 11.4% 5-ethoxy-3-(trichloromethyl)-1, 2, 4-thiodiozole—7.8 mL kg^{-1} seed]. Planting density was 17 seeds m^{-2}. Seed was covered with 25 mm of soil. Plant rows were 1 m apart.

The experimental design was a randomized complete block (split-plot) with six replications. The main plots, fumigation, were 36 m long by 9 m (nine rows) wide. The subplots, cultivar, were 6 m long by 3 m (three rows) wide. Plot treatments and plot locations in the field were the same over the 3 yr of the experiment. This permitted a measurement of treatment effects across years.

A soil sample for nematode assay was collected from the root zone of each plot at the time of planting, and 8 and 24 weeks later. Each soil sample was a composite of eight soil cores 20 mm in diameter and 150 mm deep collected from the plant row. A 100-cm^3 subsample of soil was used to determine nematode numbers by the wet sieving gravity method, with three final sievings of 45-μm mesh. The nematodes were washed from the sieve onto two layers of facial tissue supported by a 1 mm sieve on a plastic ring that fitted into a 100-mm petri dish. After 24 h, nematodes were counted with a dissecting microscope.

The number of live cotton seedlings per plot was recorded 14 and 40 days after planting. The heights of 10 randomly selected plants per plot were recorded 45, 60, and 75 days after planting. Averaged height values at each sampling date were used for statistical analysis. Seed cotton was harvested twice each year, after about 70% and then after 100% of the bolls had opened. Only total yields are presented because differences among the treatments were similar for both harvest dates.

Immediately after the second harvest each year (October), roots of 10 randomly selected cotton plants per plot were collected and rated for galls induced by *M. incognita* using a scale from 1 to 5 where 1 = no visible galls; 2 = few small galls; 3 = many small galls and few medium galls; 4 = many medium galls; and 5 = large galls. The root-gall index was equal to the mean of the 10 individual plant ratings.

An analysis of variance was calculated on each set of data for each year and across years. Least significant differences were used for comparison among treatments. Also, the root-gall index of the cultivars grown in the nonfumigated plots and the differences in yield of each cultivar grown in fumigated and nonfumigated plots were used to calculate a linear correlation.

RESULTS AND DISCUSSION

Meloidogyne incognita was the primary species of plant-parasitic nematode recovered from soil samples, but *Trichodorus* sp. and *Tylenchorhynchus* sp. were also present. Populations of these nematodes increased throughout the growing season; maximum numbers occurred 24 weeks after planting. Nematode populations were higher in soil samples from nonfumigated than from fumigated plots. *Meloidogyne incognita* was the only species that was affected significantly by fumigation or cultivar.

The average numbers of *M. incognita* second-stage juveniles were 6.0×10^5 and 2.3×10^5 m^{-3} of soil from the nonfumigated and fumigated plots, respectively, ($P = 0.04$) at 8 weeks after planting. Twenty-four weeks after planting, these populations had increased to 14.4×10^5 and 5.4×10^5 m^{-3} of soil in nonfumigated and fumigated plots, respectively ($P = 0.01$). During the growing season, *M. incognita* increased the most in the nonfumigated plots, which indicates that Telone II suppressed the buildup of *M. incognita*.

The 3-yr average population of *M. incognita* differed significantly ($P = 0.05$) among cultivars only at 24 weeks after planting (Table 1). Significantly fewer nematodes were obtained from soil samples collected from moderately resistant cultivars (Auburn 56 and LA 434RKR) than from more susceptible ones. In general, nematode populations at 24 weeks and root-knot indices (Table 2) among the cottons had similar trends, with the highest positive relationship between these two variables occurring in nonfumigated plots. Cultivars had similar ranking on the basis of root-gall indices and soil populations of *M. incognita*.

Fumigation treatments significantly affected only the root-knot gall index (Table 3). However, the fumigation by year interactions were significant for root-gall index, plant height, and lint yield. Increasing differences between nonfumigated and fumigated plots occurred each season. The respective average indices for nonfumigated and for fumigated plots were 2.8 and 1.2 in 1980, 3.3 and 1.5 in 1981, and 3.1 and 1.1 in 1982. In 1980, the average height of plants in the nonfumigated and fumigated plots was 586 and 606 mm, respectively. In 1981, their respective average plant

Table 1. Three-year average numbers of root-knot nematode second stage juveniles in soil from cottons grown for 24 weeks in nonfumigated and fumigated (Telone II) field plots.

Cultivar or line	Fumigated	Nonfumigated	Avg
		$\times 10^5$ m^{-3}	
LA 434 RKR	42	74	58
Auburn 56	16	78	47
Delcot 311	45	164	104
Coker 201	78	157	117
Stoneville 825	44	111	77
DES 56	51	139	96
M-8	99	223	161
CAMD-E	76	144	111
Deltapine 41	36	206	123
LSD (0.05)	NS	NS	46

heights were 624 and 613 mm, and there was no difference in 1982. In 1980 and 1982, fumigated plots averaged 48 and 38 kg ha^{-1} more lint, respectively, than nonfumigated plots, but in 1981 the nonfumigated plots produced 45 kg ha^{-1} more lint than the fumigated plots. The 3-yr average lint yields were not significantly different. Mean squares (Table 3) indicate significant differences for year, cultivar, and their interactions for all four characteristics, and these responses are often typical of cotton cultivars grown in the Mississippi Delta for a 3-yr period or longer.

The orders of cultivar ranking for root-knot gall index for fumigated and nonfumigated plots were similar (Table 2), but the range in galling was greater in the nonfumigated (1.9) than in the fumigated (0.5) treatment. The range in root-gall indices for several of the cotton cultivars was similar to those reported elsewhere (2, 7, 8). Root galling of plants grown in the nonfumigated plots was not as severe as it was in soils heavily infested with *M. incognita* where significant yield increases are routinely obtained with fumigant nematicides (4, 6). Most galls occurred on lateral roots near the soil surface in our test, and they were more severe on roots from nonfumigated than from fumigated plots. Root galling in fumigated plots indicated that either the amount of Telone II used did not completely control all nematodes, or the soil had become reinfested from the nontreated soil between the rows.

One of the objectives was to determine the effect of root-knot nematode on cotton lint yield. Mean squares (Table 3) did not indicate a significant yield response of any cotton cultivar to fumigation, which suggested that *M. incognita* was not a major factor in this study. However, Kappelman (1) has pointed out that steady improvement in resistance to the Fusarium wilt-root knot nematode complex has occurred in cotton cultivars developed since 1969. We have also observed that most new cultivars developed in the Mississippi River Delta during the last 20 yr have increased levels of resistance to the Fusarium wilt-root knot nematode complex (unpublished). Since the primary breeding objective in the Mississippi River Delta has been selecting for increased yield with only indirect emphasis on increased resistance to the *Fusarium* wilt-root knot nematode, it can be assumed that *M. incognita* resistance is a contributor to potential increased yields.

The analyses of variance showed a significant cultivar × fumigation interaction for gall index but did not detect a significant interaction for yield (Table 3). A more sensitive analysis for measuring the co-relationship of nematode susceptibility, as indicated by gall index and yield, is the regression analyses. This is demonstrated by using the root-gall indices of the cultivars grown in nonfumigated plots as a measure of the cultivars' root-knot nematode susceptibility and relating these indices to the cultivars' change in yield due to fumigation. A highly significant linear correlation ($P > 0.01$, $r = 0.83$) between root-gall indices of the cultivars and differences in their yields between fumigated and nonfumigated treatments was detected. This analysis is a measure of the phenotypic (genetic plus environmental) association between cultivar sensitivity and yield loss due to nematodes. We assume in light of Kappelman's (1) investigations and the local breeding progress being made for nematode resistance that most of this association is due to genetic cause and effect. This association is demonstrated in Fig. 1 as a regression equation and shows that yield decreased 35.7 kg ha^{-1} for each unit increase in root-gall index. The two statistical methods tested different but related hypotheses. The standard analysis of variance measures the consistency of cultivar differences under two management regimes and was able to detect sig-

Table 2. Three-year average root-gall indices and lint yields of nine cotton cultivars grown in fumigated and nonfumigated field plots.

Cultivar or line	Root-gall index†		Lint yield	
	Fumigated	Nonfumigated	Fumigated	Nonfumigated
			kg ha^{-1}	
LA 434	1.0	2.0	771	802
Auburn 56	1.0	2.3	654	660
Delcot 311	1.1	2.9	685	701
Coker 201	1.2	3.0	798	785
Stoneville 825	1.4	2.9	792	778
DES 56	1.3	3.2	920	871
M-8	1.4	3.5	745	717
CAMD-E	1.5	3.7	725	687
Deltapine 41	1.5	3.9	877	844
LSD (0.05)	0.3	0.3	49	49
LSD (0.01)	0.4	0.4	64	64

† 1 = no visible galls; 2 = few small galls; 3 = many small galls and few medium galls; 4 = many medium galls; 5 = large galls.

Table 3. Mean squares for root-gall index, seedling survival, plant height, and total lint yield.

Source	df	Root-knot gall index	Seedling survival	Plant height	Lint yield
Replications (R)	5	3.96	97	549	383
Fumigation (F)	1	260.00**	16	9	21
Error *a*	5	2.94	43	117	86
Cultivar (C)	8	5.50**	269**	277**	303**
C × F	8	1.86**	25	48	9
Error *b*	80	0.59	33	24	17
Year (Y)	2	5.24**	59 318**	1 178**	8 125**
Y × F	2	1.17*	46	71*	95*
Y × C	16	0.61*	163**	69**	108**
Y × F × C	16	0.27	23	22	21
Error *c*	180	0.33	42	24	22

*,** Significant *F* at the 0.05 and 0.01 probability levels, respectively.

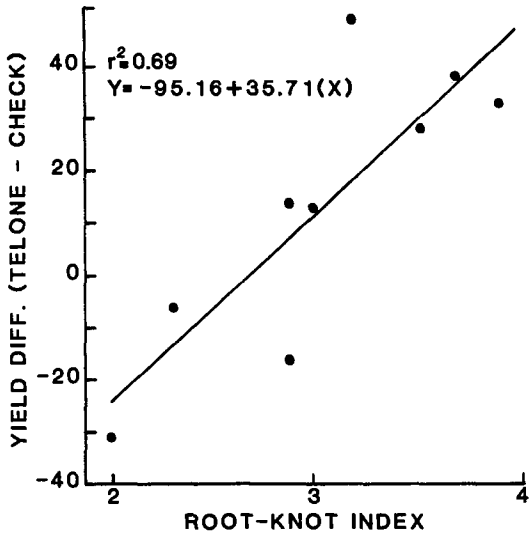

Fig. 1. Regression of root-gall index on yield differences (kg ha^{-1}) of cotton grown in Telone II treated vs. untreated field plots.

nificant differences for gall-indices but was not sufficiently sensitive to detect yield differences. The analysis of variance does not test co-relationships. Regression analysis tests the hypotheses that there is a linear relationship between yield loss in one regime and root-knot sensitivity.

The genetic analysis suggests that nematodes suppress cotton yields, but the use of the nematicide suggests no strong yield effects due to nematodes. These different conclusions may be related to other effects Telone II has on crop performance, aside from acting as a nematicide. Telone II application may have altered the competitive as well as beneficial soil microflora. This could provide an ecological advantage for some organisms and result in a reduction or increase in yield. The negative affect of the pesticide on cotton yields may vary with different cultivars. Some evidence of variable plus and minus effects due to Telone II is indicated in Table 3. The analysis of variance shows no detectable differences in yield due to the main effects of Telone II. However, the interaction of years and fumigation treatments is significant, indicating varying positive and negative effects occurred with different years, which equated to near zero when averaged over years. The yield increase obtained from using Telone II with the susceptible cultivars indicates that nematodes or possibly some other variable influenced the pesticide affect on yield. Other complex yield interactions involving Telone II and plant growth and nutrient and water uptake are also possible. This study suggests to us two problems: first, nematodes are a problem with cotton yields in the Mississippi Delta, but the problem is being addressed through breeding; second, there is need for research treatments that show a spectrum of control specifically for *M. incognita* so that more definite studies on the pest's effects can be evaluated.

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