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Chemigation for Control of Black Shank–Root-knot Complex and Weeds in Tobacco[1]

A. W. Johnson,[2] A. S. Csinos,[3] A. M. Golden,[4] and N. C. Glaze[5]

Abstract: Tank mixes of a fungicide (metalaxyl) and a nematicide (fenamiphos) with herbicides (isopropalin or pendimethalin) and an insecticide (chlorpyrifos) were applied by soil incorporation or irrigation to control the black shank–root knot complex and weeds on four tobacco cultivars. The disease complex was more severe on cultivars McNair 944, NC-2326, and K-326 than on Speight G-70. The disease complex was reduced ($P \leq 0.05$) on all cultivars with the pesticide combinations containing metalaxyl + fenamiphos. On most cultivars, percentage disease, disease index, root-gall index, yield, and weed control did not differ ($P \leq 0.05$) between the tank mixes containing isopropalin or pendimethalin or among methods of application. Generally, the most effective method of treatment application for control of the disease complex and weeds was preplant incorporated followed by postplant irrigation and preplant irrigation.

Key words: black shank, chemigation, *Meloidogyne* spp., nematode, *Nicotiana tabacum, Phytophthora parasitica,* root-knot nematode.

The application of agrichemicals through irrigation (chemigation) for control of nematodes, disease organisms, weeds, and insects has been successful (2,3,7,9–12,14). Chemigation has several advantages, particularly reduced cost, over application with tractor-powered equipment (4,21). Because about 95% of the tobacco grown in Georgia is irrigated each year, the economic advantages of chemigation over conventional application methods warrant further study. Because of irrigation needs, many growers in Georgia have located their tobacco production areas near a reliable source of water. In many of these areas, black shank, root-knot nematodes, and weeds have increased because of inadequate crop rotation. Therefore, these major pests of tobacco must be managed with resistant cultivars, chemicals, and cultural practices.

Black shank is a widespread and destructive disease in most of the flue-cured tobacco production areas of the United States. Black shank primarily affects roots and basal parts of the stem. Symptoms in young seedlings include damping off, with the stem becoming dark brown or black near the soil surface. In older plants, the stem may turn black, and leaves turn from yellow to brown, shrivel, and die within a few days. When the stem of a diseased plant is split in half lengthwise through the lesion, the pith appears dry and brown to black, and it is usually separated into plate-like disks.

Root knot is a primary disease threat to tobacco production. Black shank and root knot may coexist in the same field and cause the black shank–root knot complex on tobacco. Fenamiphos controls nematodes and metalaxyl controls black shank in tobacco (4,17,18), and both pesticides are recommended in Georgia (1). Little information is available on the control of nematodes and black shank in tobacco with fenamiphos and metalaxyl applied through irrigation water (4). Data are not available on efficacy of fenamiphos and metalaxyl in tank mixes with herbicides and insecticides for multiple pest control

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[2] Supervisory Research Nematologist, USDA ARS, Coastal Plain Station, Tifton, GA 31793.

[3] Plant Pathologist, University of Georgia, Coastal Plain Experiment Station, Tifton, GA 31793.

[4] Research Nematologist Collaborator, Nematology Laboratory, Plant Science Institute, USDA ARS, Beltsville, MD 20705.

[5] Research Plant Physiologist, USDA ARS, Coastal Plain Station, Tifton, GA 31793.

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in tobacco with these chemicals applied through irrigation water.

The objective of this research was to compare the efficacy of both fenamiphos and metalaxyl in tank mixes with herbicides (pebulate, isopropalin, or pendimethalin) and an insecticide (chlorpyrifos) applied through irrigation water or with a conventional tractor-powered sprayer-rototiller for control of black shank and root-knot nematodes in tobacco.

Materials and Methods

Plots were established in March 1986 on Fuquay loamy sand (88% sand, 8% silt, and 4% clay; pH 5.5–6.0, <2% O.M.) infested with the root-knot nematodes *Meloidogyne incognita* (Kofoid & White) Chitwood and *M. javanica* (Treub) Chitwood, *Phytophthora parasitica* Dastur var. *nicotianae* (Breda de Haan) Tucker, and weeds, primarily yellow nutsedge (*Cyperus esculentus* L.) and Texas panicum (*Panicum texanum* Buckl.). Data from heavily galled tobacco root samples collected in 1985 indicated that a mixture of *M. incognita* (range 0–49%) and *M. javanica* (range 43–100%) occurred in all field plots. *Meloidogyne arenaria* (Neal) Chitwood was found in low numbers (0 to 8% of total population) in 1985 and was not uniformly distributed in all plots. The percentage of dead tobacco plants infected with *P. parasitica* ranged from 21% to 36% on susceptible cultivars. Each experimental unit was a single row (9.8 m long) for each of four tobacco (*Nicotiana tabacum* L.) cultivars, with transplants spaced 46 cm apart (22 plants per row) in rows spaced 1.2 m apart. The experimental design was a split plot, with methods of application as whole plots, treatments as subplots, and cultivars as sub-subplots. The experiment was replicated four times.

The insecticide chlorpyrifos (3.4 kg a.i./ha) and the herbicides pebulate (4.5 kg a.i./ha) and isopropalin (2.1 kg a.i./ha) or pendimethalin (1.1 kg a.i./ha) were combined in a tank mix with metalaxyl (2.2 kg a.i./ha) and fenamiphos (6.7 kg a.i./ha). These materials were (i) applied in 280 liters spray/hectare broadcast preplant incorporated (PPI) on 26 March 1986 with a tractor-powered sprayer-rototiller to a depth of 15 cm; (ii) injected through an irrigation simulator (4) with 63.5 kiloliters water/hectare PPI; or (iii) injected through an irrigation simulator as in (ii) postplant (PP), 3 days after transplanting. A PPI sprayer-rototiller treatment consisting of pebulate, isopropalin, and chlorpyrifos served as the standard weed control treatment.

The tobacco cultivars K-326 (susceptible to *P. parasitica,* resistant to *M. incognita* races 1 and 3), McNair 944 (resistant to *P. parasitica,* susceptible to *M. incognita*), NC-2326 (susceptible to *P. parasitica* and *M. incognita*), and Speight G-70 (resistant to *P. parasitica* and *M. incognita* races 1 and 3) were transplanted 31 March. Fertilization was 560 kg/ha of 4-8-12 (N-P-K) on 17 March, 106 kg/ha of 16% sodium nitrate on 14 April, and 560 kg/ha of 4-8-12 on 22 April and 9 May. Insecticides (methomyl and acephate) and growth regulators (maleic hydrazide and fatty alcohols) were used according to University of Georgia Extension Service recommendations (13). Total rainfall during the season was 35 cm. Plots were irrigated with an additional 11.5 cm water as needed.

Plant height was recorded 7 weeks after transplanting. Leaves were harvested three times as they ripened and weighed. Total green weight was converted to dry weight using a conversion factor of 0.20, and yield per hectare was calculated for each plot (4). Numbers of living plants in each plot were recorded every 2 weeks beginning 4 weeks after transplanting until final harvest, when the percent disease and disease index (5) were calculated.

Disease index =

$$\frac{\sum_{i=1}^{n} Xi\left(100 - (i-1)\left(\frac{100}{n}\right)\right)}{Pi}$$

where i = ordinal evaluation number, n = number of evaluations (excluding initial

count), X = number of dead plants since last count, and Pi = initial number of plants in plot. A plant was considered dead when permanently wilted and when a black stem lesion was observed at or above ground level.

Twenty cores of soil, 2.5-cm-d × 25 cm deep, were collected in the row from each plot 26 March (before chemical applications), 5 May, 13 June, 22 July, and 12 August. Samples from each date were mixed thoroughly and a 150-cm^3 subsample was processed by the centrifugal flotation method (8) for nematode assay. Two plants per plot were uprooted and rated for galls 10 weeks after transplanting. All plants were uprooted and rated for galls after the final harvest. The root-gall index was based on a 1–5 scale: 1 = no galling, 2 = 1–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100% roots galled. After final harvest, root samples were collected from each cultivar in control plots for nematode species identification. Eighty *Meloidogyne* females from each cultivar were examined for species determination using perineal patterns (20). Data were analyzed using ANOVA, the Waller-Duncan multiple-range test, and multiple-stepwise regression (maximum r^2) relating yield to percentage disease, numbers of *Meloidogyne* second-stage juveniles (J2), and root galls. Treatment means were compared by linear contrasts. Only significant ($P \leq 0.05$) data are discussed.

Results

Percentage disease and disease index in K-326 and NC-2326 were lower in all treated plots than in controls and were not affected by method of application (Table 1). Percentage disease and disease index varied in McNair 944 and Speight G-70: Linear contrast of treatment means of McNair 944 indicate lower percentage disease and disease index in PPI-rototilled plots than in PPI-irrigated and control plots, and lower in PP-irrigated plots than PPI irrigated and control plots. In Speight G-70, lower percentage disease and disease index occurred in plots PPI rototilled, PPI irrigated, and PP irrigated than in controls.

Numbers of *Meloidogyne* (J2) across treatments ranged from 0 to 160/150 cm^3 soil on McNair 944, 0 to 29/150 cm^3 soil on Speight G-70, 0 to 33/150 cm^3 soil on NC-2326, and 0 to 25/150 cm^3 soil on K-326 from 5 May to 22 July (data not included). Numbers of J2 increased in all plots and on 12 August ranged from 18 to 1,560/150 cm^3 soil on McNair 944, 40 to 900/150 cm^3 soil on Speight G-70, 28 to 383/150 cm^3 soil on NC-2326, and 6 to 258/150 cm^3 soil on K-326, nor were they different among most treatments (Table 2). Linear contrasts of treatment means indicate that on NC-2326 and Speight G-70, numbers of *Meloidogyne* J2 were lower in PPI-rototilled plots than in PPI-irrigated plots. Also on NC-2326, numbers of J2 were greater in PPI-irrigated plots than in PP-irrigated or control plots. Numbers of *Meloidogyne* J2 in the soil after the final harvest were positively correlated ($P \leq 0.05$) with the final root-gall indices on all cultivars (r ranged 0.38 to 0.62).

Root-gall index means recorded 12 August from PPI-rototilled treatments were lower than those from PPI-irrigated treatments on all cultivars (Table 3). Root-gall indices of K-326 from PPI rototilled or PP irrigation treatments were lower than controls. Root-gall indices from Speight G-70 plots treated with PP irrigation were lower than those treated with PPI irrigation. Means across all treatments indicate more galling occurred on roots of McNair 944 and NC-2326 than on roots of K-326 and Speight G-70. There was a positive correlation ($P \leq 0.05$) between root-gall indices vs. percentage disease ($r = 0.49$) and disease index ($r = 0.49$) on K-326 but not on other cultivars.

Identification of *Meloidogyne* species collected from galled roots of the cultivars indicated 100% *M. javanica* on K-326, 30% *M. incognita* and 70% *M. javanica* on McNair 944, 62% *M. incognita*, 19% *M. javanica*, and 19% *M. arenaria* on NC-2326, and 100% *M. javanica* on Speight G-70.

TABLE 1. Percentage disease and disease index of four tobacco cultivars as influenced by pesticide treatments and methods of application.

Treatment†	Method of application‡	Cultivar							
		K-326		McNair 944		NC 2326		Speight G-70	
		% disease	Disease index§	% disease	Disease index	% disease	Disease index	% disease	Disease index
1. P-I-C-M-F	PPI spray/rototill	4 b	3 b	6 bc	3 b	13 b	8 b	4 bc	1 b
2. P-Pe-C-M-F	PPI spray/rototill	9 b	4 b	1 c	1 b	9 b	5 b	3 bc	1 b
3. P-I-C-M-F	PPI irrigation	14 b	6 b	60 a	23 a	28 b	8 b	3 bc	2 b
4. P-Pe-C-M-F	PPI irrigation	12 b	4 b	51 a	16 ab	28 b	9 b	14 ab	4 ab
5. P-I-C-M-F	PP irrigation	15 b	5 b	10 bc	2 b	15 b	5 b	0 c	0 b
6. P-Pe-C-M-F	PP irrigation	5 b	1 b	40 ab	14 ab	20 b	10 b	9 abc	5 ab
7. P-I-C	PPI spray/rototill	54 a	23 a	67 a	26 a	80 a	38 a	21 a	9 a
Linear contrasts‖									
1 + 2 vs. 3 + 4		NS	NS	*	*	NS	NS	NS	NS
1 + 2 vs. 5 + 6		NS	NS	NS	NS	NS	NS	NS	NS
1 + 2 vs. 7		*	*	*	*	*	*	*	*
3 + 4 vs. 5 + 6		NS	NS	*	*	NS	NS	NS	NS
3 + 4 vs. 7		*	*	NS	NS	*	*	*	*
5 + 6 vs. 7		*	*	*	*	*	*	*	*

Data are means of four replicates. Means followed by the same letter are not different ($P = 0.05$) according to Waller Duncan multiple-range test.

† P = pebulate (4.5 kg a.i./ha), I = isopropalin (2.1 kg a.i./ha), Pe = pendimethalin (1.1 kg a.i./ha), C = chlorpyrifos (3.4 kg a.i./ha), M = metalaxyl (2.2 kg a.i./ha), and F = fenamiphos (6.7 kg a.i./ha).

‡ PPI spray/rototill = broadcast preplant incorporated with a tractor-powered spray-rototiller to a depth of 15 cm in 280 liters of spray per hectare; PPI irrigation = injected through an irrigation simulator with 63.5 kiloliters of water per hectare; PP irrigation = applied as described for PPI irrigation 3 days after transplanting.

§ *Disease index = defined in text.*

‖ * indicates significant difference ($P \leq 0.05$), NS = no significant difference.

TABLE 2. Number of *Meloidogyne* species juveniles per 150 cm^3 soil at harvest on four cultivars of tobacco as influenced by pesticide treatments and methods of application.

Treatment†	Method of application‡	Cultivar			
		K-326	McNair 944	NC 2326	Speight G-70
1. P-I-C-M-F	PPI spray/rototill	9 b	463 ab	58 b	198 ab
2. P-Pe-C-M-F	PPI spray/rototill	6 b	18 b	28 b	45 b
3. P-I-C-M-F	PPI irrigation	55 ab	598 ab	383 ab	420 ab
4. P-Pe-C-M-F	PPI irrigation	258 a	1,315 a	699 a	900 a
5. P-I-C-M-F	PP irrigation	28 ab	1,560 a	176 b	40 b
6. P-Pe-C-M-F	PP irrigation	13 b	478 ab	100 b	583 ab
7. P-I-C	PPI spray/rototill	120 ab	418 ab	125 b	485 ab
Linear contrasts§					
1 + 2 vs. 3 + 4		NS	NS	*	*
1 + 2 vs. 5 + 6		NS	NS	NS	NS
1 + 2 vs. 7		NS	NS	NS	NS
3 + 4 vs. 5 + 6		NS	NS	*	NS
3 + 4 vs. 7		NS	NS	*	NS
5 + 6 vs. 7		NS	NS	NS	NS

Data in body of table are means of four replicates. Means followed by the same letter are not different ($P \leq 0.05$) according to Waller-Duncan multiple-range test.

† P = pebulate (4.5 kg a.i./ha), I = isopropalin (2.1 kg a.i./ha), Pe = pendimethalin (1.1 kg a.i./ha), C = chlorpyrifos (3.4 kg a.i./ha), M = metalaxyl (2.2 kg a.i./ha), and F = fenamiphos (6.7 kg a.i./ha).

‡ PPI spray/rototill = broadcast preplant incorporated with a tractor-powered sprayer-rototiller to a depth of 15 cm in 280 liters of spray per hectare; PPI irrigation = injected through an irrigation simulator with 63.5 kiloliters of water per hectare; PP irrigation = applied as described for PPI irrigation 3 days after transplanting.

§ * indicates significant difference ($P \leq 0.05$); NS = no significant difference.

Yield of K-326 was greater from PPI-rototilled treatments, PPI irrigation treatments, and PP irrigation treatments than from the control (Table 4). Linear contrasts of means indicate that yield of K-326 was not affected by method of treatment

TABLE 3. Root-gall indices† after final harvest of four tobacco cultivars as influenced by pesticide treatments and methods of application.

Treatment‡	Method of application§	Cultivar			
		K-326	McNair 944	NC 2326	Speight G-70
1. P-I-C-M-F	PPI spray/rototill	1.30 de	2.45 c	2.28 b	1.50 c
2. P-Pe-C-M-F	PPI spray/rototill	1.25 e	2.43 c	2.25 b	1.58 bc
3. P-I-C-M-F	PPI irrigation	2.10 ab	3.09 abc	2.98 a	1.98 ab
4. P-Pe-C-M-F	PPI irrigation	1.78 bc	3.53 a	2.78 ab	2.23 a
5. P-I-C-M-F	PP irrigation	1.53 cde	2.55 bc	2.50 ab	1.50 c
6. P-Pe-C-M-F	PP irrigation	1.68 cd	3.22 ab	2.60 ab	1.95 ab
7. P-I-C	PPI spray/rototill	2.18 a	2.38 c	2.69 ab	1.60 bc
Linear contrasts‖					
1 + 2 vs. 3 + 4		*	*	*	*
1 + 2 vs. 5 + 6		*	NS	NS	NS
1 + 2 vs. 7		*	NS	NS	NS
3 + 4 vs. 5 + 6		*	NS	NS	*
3 + 4 vs. 7		NS	*	NS	NS
5 + 6 vs. 7		*	NS	NS	NS

Data in body of table are means of four replicates. Means followed by the same letter are not different ($P \leq 0.05$) according to Waller-Duncan multiple-range test.

† Root-gall index: 1 = no galls, 2 = 1–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100%.

‡ P = pebulate (4.5 kg a.i./ha), I = isopropalin (2.1 kg a.i./ha), Pe = pendimethalin (1.1 kg a.i./ha), C = chlorpyrifos (3.4 kg a.i./ha), M = metalaxyl (2.2 kg a.i./ha), and F = fenamiphos (6.7 kg a.i./ha).

§ PPI spray/rototill = broadcast preplant incorporated with a tractor-powered sprayer-rototiller to a depth of 15 cm in 280 liters of spray per hectare; PPI irrigation = injected through an irrigation simulator with 63.5 kiloliters of water per hectare; PP irrigation = applied as described for PPI irrigation 3 days after transplanting.

‖ * indicates significant difference ($P \leq 0.05$); NS = no significant difference.

TABLE 4. Yield (kg/ha) of four tobacco cultivars as influenced by pesticide treatments and methods of application.

Treatment†	Method of application‡	Cultivar			
		K-326	McNair 944	NC 2326	Speight G-70
1. P-I-C-M-F	PPI spray/rototill	5,728 a	4,563 a	4,354 a	4,052 ab
2. P-Pe-C-M-F	PPI spray/rototill	3,813 bc	4,110 a	3,896 ab	4,145 ab
3. P-I-C-M-F	PPI irrigation	4,197 abc	2,483 b	3,571 ab	3,965 ab
4. P-Pe-C-M-F	PPI irrigation	4,497 ab	2,070 b	3,014 b	3,686 b
5. P-I-C-M-F	PP irrigation	5,318 ab	4,633 a	4,444 a	4,592 a
6. P-Pe-C-M-F	PP irrigation	5,416 ab	2,416 b	3,084 b	4,025 ab
7. P-I-C	PPI spray/rototill	2,790 c	1,815 b	1,162 c	3,656 b
Linear contrasts§					
1 + 2 vs. 3 + 4		NS	*	*	NS
1 + 2 vs. 5 + 6		NS	*	NS	NS
1 + 2 vs. 7		*	*	*	NS
3 + 4 vs. 5 + 6		NS	*	NS	*
3 + 4 vs. 7		*	NS	*	NS
5 + 6 vs. 7		*	*	*	*

Data in body of table are means of four replicates. Means followed by the same letter are not different ($P \leq 0.05$) according to Waller-Duncan multiple-range test.

† P = pebulate (4.5 kg a.i./ha), I = isopropalin (2.1 kg a.i./ha), Pe = pendimethalin (1.1 kg a.i./ha), C = chlorpyrifos (3.4 kg a.i./ha), M = metalaxyl (2.2 kg a.i./ha), and F = fenamiphos (6.7 kg a.i./ha).

‡ PPI spray/rototill = broadcast preplant incorporated with a tractor-powered sprayer-rototiller to a depth of 15 cm in 280 liters of spray per hectare; PPI irrigation = injected through an irrigation simulator with 63.5 kiloliters of water per hectare; PP irrigation = applied as described for PPI irrigation 3 days after transplanting.

§ * indicates significant difference ($P \leq 0.05$): NS = no significant difference.

application. Yield of McNair 944 was greater from PPI-rototilled treatments and the PP-irrigated treatments than from PPI irrigated treatments and the control. Yield of NC-2326 was greater from all treatments than the control. Only the PP-irrigated treatments increased yield of Speight G-70 over the control. The methods of pesticide application had no effect on yield of Speight G-70.

Yields of K-326 and Speight G-70, respectively, were inversely correlated ($P \leq 0.05$) with root-gall indices ($r = -0.37$, $r = -0.37$), percentage disease ($r = -0.74$, $r = -0.60$), and disease index ($r = -0.67$, $r = -0.57$). Yields of McNair 944 and NC-2326, respectively, were inversely correlated with percentage disease ($r = -0.87$, $r = -0.85$) and disease index ($r = -0.85$, $r = -0.85$).

A stepwise multiple-regression analysis of yield on percentage disease, numbers of J2 in the soil, and root galls showed that 55%, 76%, 72%, and 36% of the variation in yield of K-326, McNair 944, NC-2326, and Speight G-70, respectively, was caused by percentage disease. Similar combined analysis for *M. incognita*-resistant cultivars K-326 and Speight G-70 and *M. incognita*-susceptible cultivars McNair 944 and NC-2326 showed that 36% and 5%, respectively, of the variation in yield was caused by percentage disease and numbers of *Meloidogyne* J2 in the soil at final harvest. Similar analysis for *P. parasitica*-resistant cultivars McNair 944 and Speight G-70 and susceptible cultivars K-326 and NC-2326 showed that 75% and 64%, respectively, of the variation in yield was caused by percentage disease. An additional 3% of the variation in yield of K-326 and NC-2326 was caused by root galls.

The standard weed control treatment (pebulate + isopropalin) provided 88% total weed control (data not presented). None of the treatments provided better ($P \leq 0.05$) total weed control than the standard treatment. The PPI irrigation treatment containing isopropalin provided 48% total weed control, but other treatments provided 59–88% total weed control. The composition of weed escape populations were yellow nutsedge (65–90%), Texas panicum (8–33%), and other weeds

(0–2%). There was no difference in percentage composition of weed escapes among treatments compared to the standard weed control treatment.

Discussion

The black shank–root knot disease complex was greater on McNair 944, NC-2326, and K-326 than on Speight G-70, essentially following the known levels of resistance in these cultivars. The disease complex was reduced on all cultivars, with the pesticide combinations including metalaxyl + fenamiphos. Percentage disease, disease index, root-gall index, yield, and weed control did not differ between the tank mixes containing isopropalin and pendimethalin or the methods of application on most cultivars. Generally, the most effective method of treatment application for control of nematodes and black shank was PPI spray-rototill, followed by PP irrigation and PPI irrigation. Our data demonstrate that application of metalaxyl + fenamiphos in tank mixes containing herbicides and an insecticide through irrigation water PPI and PP has similar potential to PPI application in controlling the black shank–root knot disease complex and weeds. These results agree with those reported for fenamiphos applied postplant for nematode control on other crops (11).

Some tobacco cultivars have resistance to *M. incognita* (races 1 and 3), which is among the most common *Meloidogyne* species in the Southeast. Powell and Nusbaum (16) reported that *M. incognita incognita* and *M. incognita acrita* were the only two species important as pathogens of tobacco in North Carolina in 1960. More recently, *M. javanica* and *M. arenaria* have been reported to be important pathogens on flue-cured tobacco in the southeastern Coastal Plain (6,15,18,19). We reported that, in soil infested with mixed populations of root-knot nematodes, a selection from predominately *M. incognita* to *M. javanica* occurred when cultivars NC-95 and Speight G-28, resistant only to *M. incognita*, were planted (4). Our results in this study indicate similar selections when Speight G-70 and K-326 resistant to *M. incognita* were infected only by *M. javanica*. Most of the 21% disease in control plots of Speight G-70 was caused by the predominant invasion of roots by *M. javanica*. Our data suggest that in fields with mixed infestations, utilization of cultivars resistant to *M. incognita* may cause emergence of other predominating species.

Effects of nematode damage on severity of black shank have been reported (4,16, 18) and further substantiated with our data. Cultivars containing resistance to *M. incognita* showed less black shank disease than cultivars without resistance to *M. incognita*. In cultivars containing resistance to *P. parasitica*, more black shank occurred in McNair 944 susceptible to *M. incognita* and *M. javanica* than in Speight G-70 resistant to *M. incognita*.

It is important for growers to identify the species of *Meloidogyne* in their tobacco production fields and select appropriate pest-management strategies to reduce losses caused by the black shank–root knot disease complex. Application of tank-mixed pesticides through irrigation water may be an effective and economical method of pesticide delivery (4,12,21). More research is needed on the relationship of soil moisture, time of pesticide application, and volume of water to use during application. Application technology, as described herein, will reduce unit production cost and provide growers more information for decision-making in tobacco production.

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