EFFECTS OF PLANTING DATES, METALAXYL, AND FENAMIPHOS ON THE TOBACCO BLACK SHANK-ROOT KNOT COMPLEX, TOBACCO QUALITY, AND YIELD

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Tobacco transplanted 5 April tended to have a higher incidence of black shank disease than tobacco transplanted 5 May in 1983. The combination of metalaxyl and fenamiphos reduced black shank disease in both plantings over the untreated control. Yields were higher in the 5 May planting than in the 5 April planting, except for one treatment in which there were no differences. In 1984, black shank was reduced by all treatments for the 6 April and 15 May plantings, and by all treatments containing metalaxyl for the 26 April planting. Generally, black shank was reduced for a particular treatment as the transplanting date was delayed. For all three transplanting dates in 1984, root-knot indices were reduced by treatments having fenamiphos. There was a general trend for a reduction in root-knot damage as the transplanting date was delayed. Generally, yields tended to decline as the transplanting date was delayed. Value/ha correlated with yields. The grade index tended to be higher in the 26 April planting compared to the 6 April and 15 May plantings. Nitrogen content of leaves was not different for any treatment. However, total alkaloids and percent reducing sugars differed in some of the chemical treatments.

Additional key words: ***Nicotiana tabacum*, *Phytophthora parasitica* var. *nicotiana*, *Meloidogyne incognita*, *Meloidogyne javanica*.**

INTRODUCTION

Black shank, which is incited by *Phytophthora parasitica* Dastur var. *nicotianae* (Breda de Haan) Tucker, is one of the most serious fungal diseases of tobacco (*Nicotiana tabacum* L.) in the United States (7). The *Meloidogyne* nematode species *M. incognita* (Kofoid & White) Chitwood, *M. javanica* (Treub.) Chitwood, and *M. arenaria* (Neal) Chitwood also are destructive pathogens of tobacco in the Georgia Coastal Plain (1,3,13). Alone, both pathogens may cause high losses to tobacco, but nematodes also increase losses due to black shank when these pathogens occur together (11). Life cycles of *Meloidogyne* spp. and *P. parasitica* var. *nicotianae* are short in the warm, moist soils of the southeastern USA, and they may go through several cycles in a single season. Damage by one or both pathogens may be dependent on environmental conditions during the season (1,3,8,11). Management practices for black shank and root-knot nematodes include the use of resistant cultivars (9), rotations, and applications of metalaxyl and nematicides (1,2,12,13,15).

Variations in the amount of black shank from year to year have been noted in fields that are infested with *P. parasitica* var. *nicotianae*. This study was initiated to determine the effects of transplanting dates on the severity of tobacco black shank and root-knot nematodes and on the subsequent quality, value, and yield of tobacco treated with metalaxyl and fenamiphos.

MATERIALS AND METHODS

Experiments were established in 1983 and 1984 at the Coastal Plain Experiment Station near Tifton, Georgia, on fuquay, loamy sand (loamy siliceous, thermic Arenic Plinthic Kandiudults; 88% sand, 8% silt, and 4% clay; pH 5.5-6.0; <2% organic matter) in an area infested with *P. parasitica* var. *nicotianae*, *M. incognita*, and *M. javanica*. The tobacco cultivar NC 2326, which has no resistance to nematodes and low resistance to black shank, was used both years. Each plot consisted of two rows that were 10-m long. Plants were spaced 46-cm apart within rows, and rows were 1.2-m apart.

In 1983, tobacco was transplanted on two different dates (5 April = Planting I, and 5 May = Planting II) into adjacent plots within the same field. Each planting date had four chemical treatments and an untreated control arranged in a randomized complete block design with four replications.

In 1984, three transplanting dates and four chemical treatments were included in a 3 x 4 factorial experiment with each treatment combination replicated four times and arranged in a randomized complete block design. The three transplanting dates in 1984 were 6 April (Planting I), 26 April (Planting II), and 15 May (Planting III).

Plot land was prepared for planting by deep turning the soil with a moldboard plow and disc harrowing. In 1983, treatments consisted of (a) metalaxyl (Ridomil®, Ciba Inc.) applied at 2.24 kg (ai)/ha, (b) fenamiphos (Nemacur®, Miles Inc.) at 6.7 kg (ai)/ha, (c) metalaxyl at 2.24 kg (ai)/ha plus fenamiphos at 6.7 kg (ai)/ha preplant incorporated (PPI), and (d) metalaxyl at 1.12 kg (ai)/ha plus fenamiphos at 6.7 kg (ai)/ha PPI and metalaxyl at 0.56 kg (ai)/ha at layby (L). The layby treatment was applied six weeks post-transplanting as a directed spray, and it was incorporated by cultivation. In 1984, chemical treatments consisted of (a) metalaxyl applied at 2.24 kg (ai)/ha PPI, (b) fenamiphos applied at 6.7 kg (ai)/ha PPI, and (c) metalaxyl at 2.24 kg (ai)/ha plus fenamiphos at 6.7 kg (ai)/ha tank mixed and applied PPI. In both years, PPI treatments were applied at 187 L/ha with a boom sprayer mounted in front of a tractor-powered rototiller, which was used to incorporate the chemicals to a depth of 15 cm.

Fertilizer was applied according to the University of Georgia Cooperative Extension Service recommendations based on soil tests. Insecticides (methomyl, chlorpyrifos, and acephate), herbicides (pendemethalin, pebulate, and isoproplin), and growth regulators for sucker control (maleic hydrazide and fatty alcohols) also were used according to Cooperative Extension Service recommendations (9). Rainfall was recorded and supplemented with overhead irrigation as required. Total rainfall in 1983 for Planting I and Planting II was 38 cm and 31 cm, respectively, and each planting received 14 cm of supplemental irrigation. Total rainfall in 1984 for Plantings I, II, and III was 53, 41, and 39 cm, respectively. All plots were irrigated with a total of 5 cm of water in 1984.

The number of living plants in each plot was counted and recorded every two weeks starting four weeks after transplanting, and the percentage of black shank-infected plants (percent disease) and the disease index were calculated. The disease index was calculated using the formula:

$$DI = \frac{\sum_{i=1}^{n} X_i(100-(i-1)\frac{100}{n})}{I}$$

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Table 1. Effects of chemical treatments and planting dates on the incidence of tobacco black shank, disease index, and yield, 1983.

	Chemical treatments						Planting dates[a]		
Variables	C[b]	M[c]	F[c]	M+F[c]	M+F[d]	SE[b]	I	II	SE[b]
Disease (%)	89 a[e]	50 b	85 a	19 c	18 c	5.2	65 a	39 b	2.6
Disease index	45 a	19 b	40 a	5 c	5 c	2.5	27 a	19 b	1.2
Yield (kg/ha)	665 c	2532 b	1052 c	4023 a	4014 a	221.1	1841 b	3073 a	93.7

[a] Planting dates were 5 April (I) and 5 May (II).
[b] C = Untreated control, and SE = Standard error of least-squares means.
[c] Metalaxyl (M) was applied at 2.24 kg ai/ha preplant incorporated (PPI), and fenamiphos (F) was applied at 6.7 kg ai/ha PPI.
[d] Metalaxyl (M) was applied at 1.12 kg ai/ha PPI and 0.56 kg ai/ha at layby, and fenamiphos (F) was applied at 6.7 kg ai/ha PPI. PPI treatments were applied before transplanting and incorporated to a depth of 15 cm. The layby treatment was applied at six weeks post-transplanting as a directed spray and incorporated by cultivation.
[e] Treatments or planting date means within a row followed by the same letter are not significantly different ($P < 0.01$).

where i = ordinal evaluation number, n = number of evaluations (excluding initial stand count), X = number of dead plants since last count, and I = initial number of plants (1). A plant was considered dead when it was permanently wilted and a black lesion was observed on its stem extending from ground level. Nematode determinations were made in 1984 by bulking 20 random soil cores (2.5-cm diam x 25-cm deep) in each plot, mixing the soil, and removing 150 cm^3 for soil assay on three different dates (3 April, 16 July, and 4 September). The centrifugal flotation technique (6) was used to recover nematodes from the soil. In 1984, a final root-knot index was determined by uprooting all living plants after final harvest and rating them for percent of roots galled (1).

In 1983, leaves were hand-harvested beginning on 19 July and 22 July for Plantings I and II, respectively. Remaining harvests were done on 4 August, 17 August, and 22 August for both planting dates, as leaves ripened in 1983. In 1984, leaves were hand-harvested as they ripened on 23 July, 15 August, and 30 August for Planting I; on 1 August, 23 August, and 30 August for Planting II; and on 8 August, 30 August, and 17 September for Planting III. The weight of leaves from each plot was recorded at each harvest. Total fresh weight for each plot was converted to dry weight using a 0.2 conversion factor (1), and yield per hectare was calculated for each plot.

Percent total nitrogen, total alkaloids, and reducing sugars were determined on tobacco leaves of all plantings in 1984. Sample preparation and chemical analyses of tissue were performed as outlined by Gaines (4).

Tobacco was graded after curing by U. S. Department of Agriculture graders. Grade index was a numerical value that ranged from 1 to 99 based on equivalent government grades (16); the higher the number, the higher the grade. Values were calculated by multiplying the average price per kilogram of weight for the grade times the weight of tobacco per hectare.

Data were analyzed using PROC GLM of SAS (14). The statistical model included effects due to chemical treatment, replicate within chemical treatment (main plot error), planting date, and treatment X planting date interaction. Treatment effect was tested using the replicate within treatment mean square. Correlation coefficients (r) between yield and disease traits were computed and presented if significant.

RESULTS

1983

Least-squares means (14) for the 1983 experiments are presented in **Table 1**. The percentage of plants infected with black shank and the disease index were significantly lower and yields were significantly greater in plots treated with both metalaxyl and fenamiphos than they were in plots where these materials were used alone. Metalaxyl alone controlled black shank better and increased yields more than fenamiphos alone.

There were significant differences between the two planting dates for all three variables (**Table 1**). The percentage of diseased plants and the disease index were lower and yields were greater in Planting II than in Planting I.

Yields for Planting I and Planting II were negatively and significantly correlated with the percentage of diseased plants (r = -0.96, P = 0.001; and -0.97, P = 0.001, respectively) and with the disease index (r = -0.98, P = 0.001; and -0.97, P = 0.001, respectively).

1984

Least-squares means combined across planting dates for the variables in the 1984 experiment are presented in **Table 2**. Plots treated with a combination of metalaxyl and fenamiphos had a lower percentage of plants infected with tobacco black shank, a lower disease index, a higher value per hectare, and

Table 2. Effects of chemical treatments and planting date on black shank, root-knot nematode damage, yield, and quality characteristics on tobacco, 1984.

	Chemical treatments (T)					Planting dates[a] (PD)				
Variables	M[b]+F[b]	M[b]	F[b]	C[c]	SE[c]	I	II	III	SE[c]	T X PD Interaction[d]
Disease (%)[e]	3 c[f]	31 b	26 b	57 a	4.0	41 a	20 b	25 b	3.3	NS
Disease index[e]	1 c	8 b	8 b	19 a	1.3	13 a	6 b	8 b	1.0	*
Root-knot index	40 b	85 a	23 b	71 a	7.1	61 a	61 a	42 b	2.6	*
Grade index	34 a	39 a	34 a	35 a	3.1	35 b	48 a	35 b	1.6	NS
Value ($/ha)	18058 a	10806 b	13731 b	6310 c	937.2	12226 a	13052 a	9129 b	468.6	NS
Yield (kg/ha)	4205 a	2751 b	3305 b	1793 c	265.1	3159 a	3300 a	2581 a	121.2	NS

[a] Planting dates I, II, III were on 6 April, 26 April, and 15 May 1984, respectively.
[b] Metalaxyl (M) was applied at the rate of 2.24 kg ai/ha preplant incorporated (PPI), and fenamiphos (F) was applied at the rate of 6.7 kg ai/ha PPI.
[c] C = Untreated control, and SE = Standard error of least-squares means.
[d] * indicates planting date x treatment interaction was significant ($P < 0.05$); NS indicates the interaction was not significant at the 0.05 probability level.
[e] For tobacco black shank.
[f] Treatment or planting date means within a row followed by the same letter are not significantly different ($P < 0.05$).

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Table 3. Effects of chemical treatments and planting dates on the numbers of root-knot larvae/150 cm^3 soil.

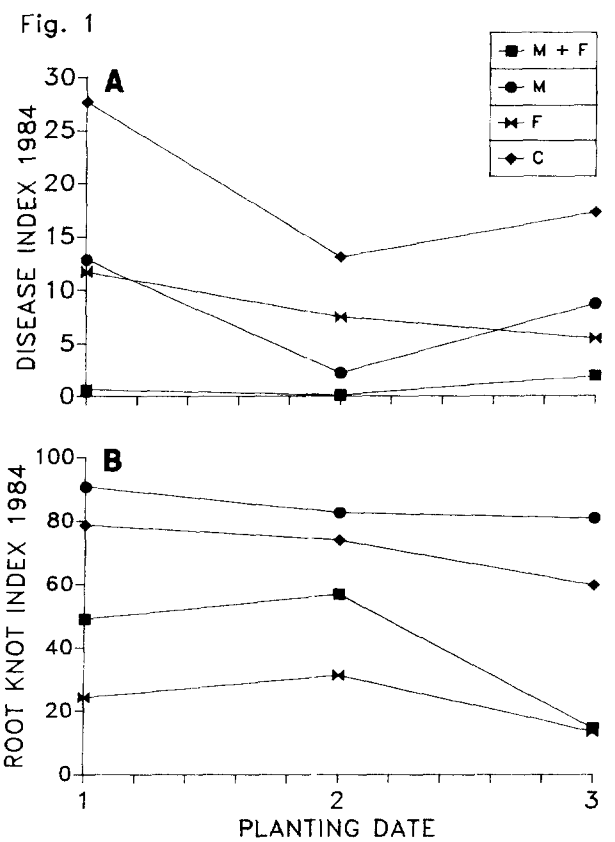
Chemical treatment & Rate (kg [ai]/ha)	3 April Planting I	3 April Planting II	3 April Planting III	16 July Planting I	16 July Planting II	16 July Planting III	4 September Planting I	4 September Planting II	4 September Planting III
Metalaxyl (2.24) + Fenamiphos (6.7)	96 a[a]	94 a	100 a	10 c	5 a	3 a	470 b	2058 ab	785 ab
Metalaxyl (2.24)	40 a	108 a	104 a	113 ab	78 a	8 a	1000 ab	903 b	2755 a
Fenamiphos (6.7)	54 a	70 a	76 a	18 bc	3 a	0 a	1000 ab	3740 a	83 b
Untreated Control	108 a	30 a	148 a	148 a	123 a	3 a	2563 a	268 b	2605 a

[a] Means within a column followed by the same letter are not significantly different ($P < 0.05$). Root-knot juvenile numbers were not significantly different across planting dates.

a higher yield than plots with any other chemical treatment. Treatments with fenamiphos alone or with metalaxyl alone reduced the percentage of diseased plants, reduced the disease index, increased yields, and increased value per hectare over the control plots. Only treatments containing fenamiphos reduced the root-knot index.

The percentage of plants infected with tobacco black shank and the disease index were greater for plots in Planting I than in plots planted later (**Table 2**). Root-knot damage was less for plots in Planting III than for plots planted earlier, and grade index was greatest for plots in Planting II than for the other two planting dates. Although no difference occurred in yields across planting dates, value per hectare was greater for plots in Planting I and Planting II than those in Planting III. Significant interactions occurred between treatment and planting date for disease index and root-knot index (**Figure 1**). For these parameters, the effects of chemical treatments were not similar across planting dates. The efficacies of the chemical treatments were dependent on the planting date. The severity of black shank and root-knot nematode damage in the absence of a chemical treatment tended to be less as planting date was delayed. This trend also was seen for most chemical treatments, except for metalaxyl used alone.

Figure 1. (A) Effect of planting date on black shank (disease index) in tobacco and response to chemical treatments. C = untreated control, F = fenamiphos at 6.7 kg ai/ha, M = metalaxyl at 2.24 kg ai/ha, and M + F = metalaxyl at 2.24 kg ai/ha plus fenamiphos at 6.7 kg ai/ha. (B) Effect of planting date on root-knot nematode damage and response to chemical treatments.



For all three planting dates, yields were negatively and significantly correlated with the percentage of black shank infected plants (r = -0.89, $P = 0.0001$; r = -0.74, $P = 0.001$; and r = -0.85, $P = 0.001$, respectively) and with disease index (r = -0.86, $P = 0.0001$; r = -0.77, $P = 0.0005$; and r = -0.78, $P = 0.0003$, respectively). Yield also was significantly and negatively correlated with root-knot index for Planting III (r = -0.60, $P = 0.01$).

Before the 1984 experiment, soil populations of root-knot nematode juveniles were relatively high (30-148/150 cm^3 soil) (**Table 3**). Generally, nematodes declined early in the season, but population densities increased to a relatively high level by final harvest. In Planting I, the metalaxyl plus fenamiphos treatment had significantly fewer juveniles than the control plots (2605/150 cm^3 soil) by the end of the season. Numbers of nematodes in Planting II did not follow the same trend as in Plantings I and III, and we have no explanation for this variation. Significant differences were not detected among planting dates for any treatment.

Significant differences occurred in total nitrogen, total alkaloids, and reducing sugars among chemical treatments and among planting dates (**Table 4**). Some trends were noted across harvest dates; notably, total nitrogen and total alkaloids tended to increase from first harvest to third harvest.

DISCUSSION

Our results corroborate those of Powell & Nusbaum (11), indicating that an interaction between root-knot nematodes and *P. parasitica* var. *nicotianae* in tobacco occurs. Control of both pests was necessary to obtain maximum tobacco yields. In 1983, the split application (PPI + L) at a total rate of 1.68 kg/ha of metalaxyl was as effective as the single application (PPI) of 2.24 kg/ha.

Under the conditions experienced in North Queensland, O'Brien et al. (10) were able to reduce losses from black shank by planting tobacco during the winter when soil temperatures were cooler. In our experiment during 1983, there was a trend toward a higher level of black shank disease and a lower yield in tobacco planted 5 April than in tobacco planted 5 May. Again, in 1984, disease ratings and nematode indices tended to be greater in the early planting than in the midseason and late plantings. However, yields did not necessarily correlate with these trends. Yields generally were higher the earlier the tobacco was planted in 1984. Variations from this general trend occurred in plots treated with chemicals that affect control of either the fungus or the nematode or both. The use of early planting dates in Australia was probably successful in reducing tobacco black

Table 4. Effects of chemical treatments and planting dates on total nitrogen, total alkaloids, and reducing sugars of cured tobacco for three harvests.

	Chemical treatments					Planting dates[a]			
Variables[b]	M+F[c]	M[c]	F[c]	C[d]	SE[d]	I	II	III	SE[d]
HARVEST 1									
TN	1.83 a[e]	1.80 a	1.90 a	2.05 a	0.12	1.99 a	1.90 ab	1.79 b	0.07
TALK	2.40 b	2.49 ab	2.67 ab	2.86 a	0.14	2.77 a	2.82 a	2.22 b	0.09
RSUG	15.52 a	15.46 a	14.03 a	15.26 a	1.33	15.67 a	16.06 a	13.47 b	0.64
HARVEST 2									
TN	1.86 a	1.86 a	1.96 a	2.01 a	0.08	1.91 a	2.02 a	1.85 a	0.06
TALK	3.24 a	3.30 a	3.36 a	3.35 a	0.19	3.23 b	3.79 a	2.92 b	0.13
RSUG	18.29 a	17.67 ab	17.32 ab	15.84 b	0.78	17.61 a	16.92 a	17.31 a	0.53
HARVEST 3									
TN	2.15 a	2.20 a	2.36 a	2.31 a	0.09	2.37 a	2.15 b	2.24 ab	0.07
TALK	3.58 b	4.02 a	3.56 b	4.25 a	0.13	3.77 b	4.14 a	3.65 b	0.11
RSUG	15.81 a	14.77 ab	15.57 a	13.75 b	0.54	15.39 a	16.58 a	12.95 b	0.43

[a] Planting dates I, II, III were on 6 April, 26 April, and 15 May 1984, respectively.
[b] TN=total nitrogen, TALK=total alkaloids, RSUG=reducing sugars.
[c] Metalaxyl (M) was applied at the rate of 2.24 kg ai/ha preplant incorporated (PPI), and fenamiphos (F) was applied at the rate of 6.7 kg ai/ha PPI.
[d] C = Untreated control, and SE = Standard error of the least squares means.
[e] Treatment or planting date means within a row followed by the same letter are not significantly different ($P < 0.05$).

shank because cooler soil temperatures delay the onset of this disease (8). The average frost-free period for the southern part of Georgia is from 15 March to 15 November. Apparently, soil temperatures and moisture in a given year may influence the infection rate of black shank more than strictly the planting date does. In the tobacco growing belt of Georgia, the acceptable planting window from late March through early May apparently does not provide sufficient climatic variation to prevent losses from either black shank or root-knot nematode by varying planting date alone. Consistent reduction of losses to these parasites was achieved only by the use of a fungicide and a nematicide. Variations in rainfall or soil temperature may be sufficient to increase or decrease losses from black shank from year to year (8), but the unpredictability of these variables in Georgia dictates the use of a fungicide to manage this pest problem. In addition, statistical analysis revealed that the efficacies of chemical treatments were dependent on planting dates.

Nitrogen levels in cured leaves were unaffected by chemical treatments for any of the three harvests, but they tended to be reduced at later planting dates. Alkaloid levels tended to decrease with improved disease control and with delayed planting dates. Reducing sugars tended to increase with improved disease control, and they tended to decrease as planting date was delayed. Under situations of high disease and nematode pressure, subtle reductions on the quality of tobacco may occur (5).

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