Journal of Nematology 16(3):240–245. 1984.


# Population Development and Pathogenicity of *Meloidogyne javanica* on Flue-cured Tobacco as Influenced by Ethoprop and DD[1]

J. R. Rich, C. Hodge, and J. T. Johnson[2]

*Abstract:* Growth of flue-cured tobacco as influenced by *Meloidogyne javanica* and the effectiveness of DD and ethoprop to manage this nematode were evaluated over two growing seasons. Populations of *M. javanica,* root galling, plant height, steam crown diameter, whole plant weight, and yield were monitored at approximately 2-week intervals beginning 28 days after transplanting. Treatment influence on nematode population development, root galling, and plant growth generally followed a pattern in descending order of efficacy: DD (187 liters/ha), ethoprop (27, 18, or 9 kg a.i./ha), and control. In all treatments, nearly season-long increases in *M. javanica* populations and root galling were observed. Correlation coefficients relating nematode populations or root galling to final tobacco yield suggested either method may be used successfully to evaluate nematicide efficacy in research plots. Plant growth parameters most affected by *M. javanica* in order of decreasing severity were cured leaf yield, whole plant weight, plant height, and stem diameter.

*Key words:* root-knot nematode, nematicides, *Nicotiana tabacum.*

Root-knot nematodes, *Meloidogyne* spp. Chitwood, are major pathogens of tobacco in Florida (10) and worldwide (12). Three species of *Meloidogyne* are present in Florida tobacco fields: *M. arenaria* (Neal) Chitwood, *M. incognita* (Kofoid & White) Chitwood, and *M. javanica* (Treub) Chitwood. Although *M. javanica* has long been known as a major parasite of tobacco in other parts of the world (13,15,19), it has been recognized only recently as a major nematode problem of this crop in Florida (17). In 1961, Graham (6) first observed *M. javanica* on tobacco from a breeding nursery at the University of Florida. According to him, the nematode was rarely found in Georgia, North Carolina, or South Carolina, implying it occurred more frequently in Florida than further north. Loh and Miller (11) also suggested that within the United States, *M. javanica* infestations may be unique to tobacco production only in Florida and extreme South Georgia. In 1977, *M. javanica* was detected in 53% of the Florida tobacco fields surveyed (17) while in 1981, this nematode was detected in over 65% of tobacco fields sampled (Garcia and Rich, unpubl.). Presently, most tobacco yield losses from nematodes in Florida are caused by *M. javanica.*

In microplot tests, *M. javanica* was more aggressive on tobacco than either *M. arenaria* or *M. incognita,* and populations of *M. javanica* developed more rapidly than those of *M. incognita,* resulting in greater early season damage (1,3). In growth chamber studies, *M. javanica* invaded tobacco roots more rapidly and produced larger root galls than *M. arenaria* or *M. incognita* (2). The rapid population development and greater root galling potential of *M. javanica* may explain the extensive damage caused by this species in Florida tobacco. The biology, pathogenicity, and management of *M. javanica* on tobacco under field conditions is poorly understood. A study was designed to investigate 1) *M. javanica* population development and tobacco root galling response over a growing season, 2) the correct time to sample research plots to correlate nematode populations and root galling to cured leaf yields, 3) the influence of *M. javanica* on the seasonal growth patterns of tobacco, and 4) the comparative efficacy of a commonly used nonfumigant and fumigant nematicide.

## Materials and Methods

Field experiments were conducted in 1978 and 1979 on a Chipley fine sand (89% sand, 8% silt, 3% clay) naturally infested with *M. javanica.* In 1978, 187 liters/ha of DD (1,2-dichloropropane-1,3-dichloro-

Received for publication 31 August 1983.

[1] Florida Agricultural Experiment Station, Journal Series 4950.

[2] Respectively, Associate Professor, Laboratory Technician II, and Associate Professor, University of Florida, IFAS, Agricultural Research Center, P.O. Drawer 1210, Live Oak, FL 32060. Present address of third author: University of Georgia, Cooperative Extension Service, Athens, GA 30602.

propene and related $C_3$ hydrocarbons) were injected broadcast on 30-cm chisel spacings, 25 cm deep, 3 weeks before transplanting tobacco. Ethoprop 10G (O-ethyl S,S-dipropyl phosphorodithioate) at 9.0 and 27.0 kg a.i./ha was broadcast and incorporated 9–13 cm deep by disking twice 2 weeks before transplanting. Soil in all treatments was bedded at this time. On 29 March, 'McNair 944' tobacco (*Nicotiana tabacum* L.) was planted 50 cm apart in rows 1.2 m wide. Four row plots, 8.23 m long, were arranged in a randomized complete block with six replications. Normal cultural practices for tobacco were followed including irrigation as needed. Three times over the season tobacco leaves were harvested as they matured.

Soil samples for nematode population measurements and cured leaf yields were obtained from the center two rows of each plot. Root-gall index, plant stem crown diameter, plant height, and whole plant dry weights were recorded from two randomly selected plants in the outside plot rows. All data except cured leaf yield were collected about every 2 weeks beginning 28 days after transplanting. Eight soil cores, 2.5 cm d × 30 cm deep, were collected randomly from each plot 13 cm from the base of the tobacco plants. A 250-$cm^3$ aliquant of mixed soil was processed by a modified centrifugal-flotation technique (8). Root-gall indices were based on a 0–4 scale with 0 representing no galling of the root system and 4 representing greater than 75% galling.

The 1979 test was conducted similarly to that of 1978 with the following exceptions: DD was applied 2 weeks before transplanting, and ethoprop 6 EC was applied at 9.0 and 18.0 kg a.i./ha 1 day before transplanting. In addition to the juveniles in soil, nematode eggs were extracted from roots contained in the 250-$cm^3$ soil samples (7). Data were collected at 2-week intervals beginning 28 days after transplanting.

When measured early in the season in both 1978 and 1979, some data were very low or highly variable, and these were not included in tables and figures.

## Results

In the 1978 test, soil populations of *M. javanica* juveniles remained low until after 56 days from transplanting, and populations were different among treatments at 70 and 84 days (Fig. 1A). In 1979, *M. javanica* juvenile and egg numbers increased rapidly after 42 days in the control plots, while in all other treatments the increases were gradual until after 56 days (Fig. 1B). Nematode populations began to decline after 84 days in all treatments except the DD. Differences in nematode populations between the control and other treatments were observed at all but the 42 day sampling date, while population differences among the chemical treatments were observed only at 42 days.

In 1978, little early season root galling was observed, and data were not recorded until 56 days after transplanting (Fig. 1C). Root galling increased rapidly between 56 and 70 days and modestly thereafter in all treatments except DD where a pronounced increase was observed after 70 days. Differences in root galling among treatments were found at all sampling dates. Generally, the control and 9 kg a.i./ha ethoprop treatment resulted in the highest root galling followed by the DD and 27 kg a.i./ha ethoprop treatments. In 1979, root galling was measurable at 28 days after transplanting on plants in the control plots (Fig. 1D). A large increase in root galling occurred in control plots between 28 and 56 days after transplanting, whereas only slight increases were observed in the nematicide treatments. Root galling increased in all treatments between 56 and 84 days and reached the maximum in control plots at 84 days. Differences in root galling among treatments were observed at all sampling dates, with greatest differences occurring between the control and other treatments.

Plant heights in 1978 were not affected by nematicide soil treatments, and they increased rapidly in all plots between 42 and 70 days after transplanting (Fig. 2A). Similar growth patterns were observed in 1979, but differences in plant heights among treatments were found at 42 days after transplanting and later (Fig. 2B). The decline in plant heights after 70 days in both years was due to removal of the inflorescences. Over the 1979 season, tallest plants grew in soil treated with DD followed in descending order by the two ethoprop (18

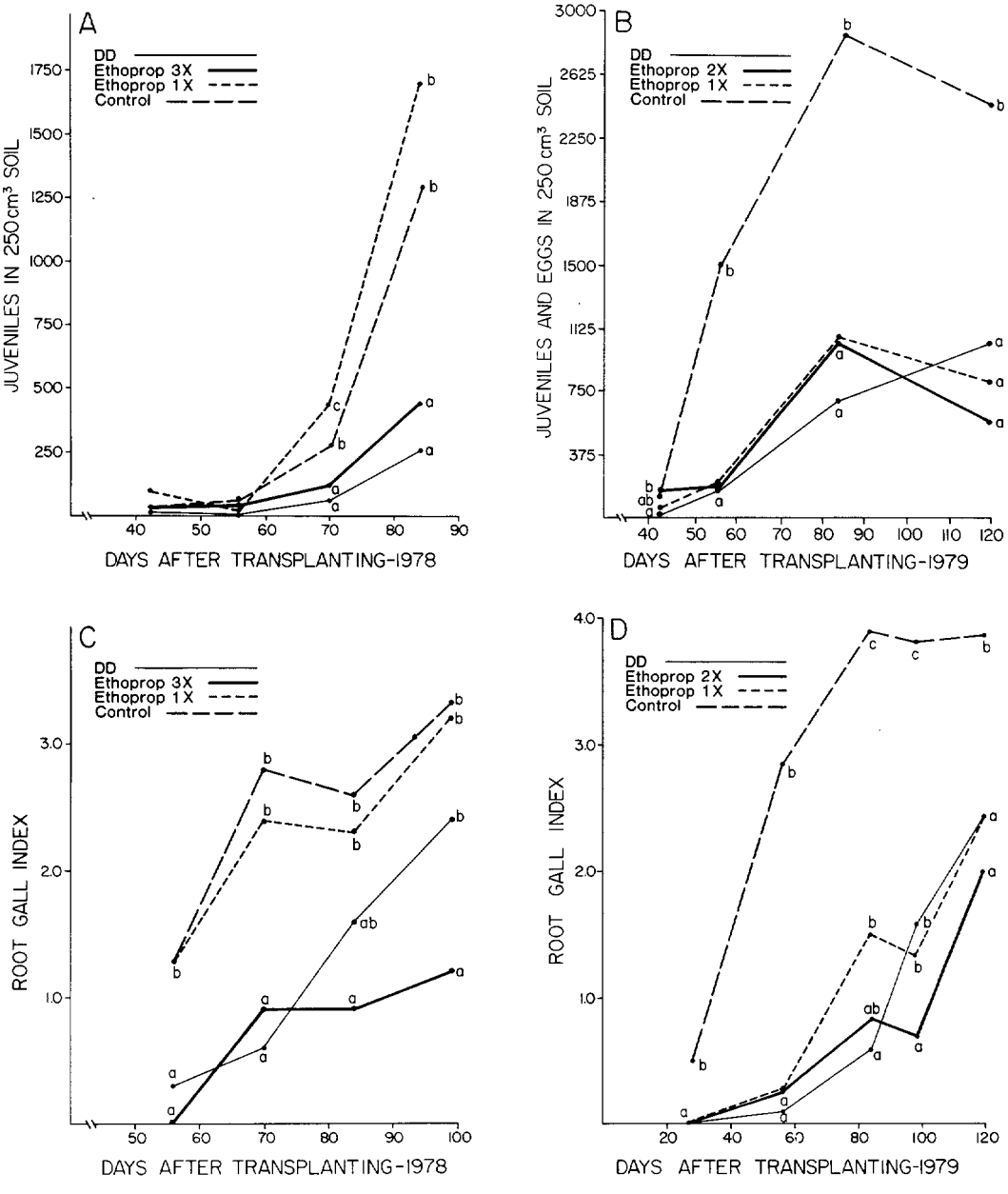


FIG. 1. Influence of DD and ethoprop on *Meloidogyne javanica* juveniles and egg population levels. A) *M. javanica* juveniles/250 cm³ soil in 1978. B) *M. javanica* juveniles and eggs/250 cm³ soil in 1979. C, D) Root-gall index, 0–4 scale with 0 = no galling, 4 = >75% root galling in 1978 and 1979. DD applied at 187 liters/ha, ethoprop at 27 kg (3 ×), 18 kg (2 ×) or 9 kg a.i./ha (1 ×). Points on the same date followed by the same letter are not different ($P \leq 0.05$) according to Duncan's multiple-range test.

and 9 kg a.i./ha) and control treatments. No differences were found in stem diameter among treatments at any sampling date in 1978 and 1979. Highest average stem diameter of mature tobacco was 2.8 cm, which was reached at 70 days from planting in 1978 and 84 days in 1979. Cumulative tobacco dry weights increased throughout the season in 1978 (Fig. 2C), but differences among treatments were observed only at 98 days. Plant growth patterns were similar in 1979, but differences in top

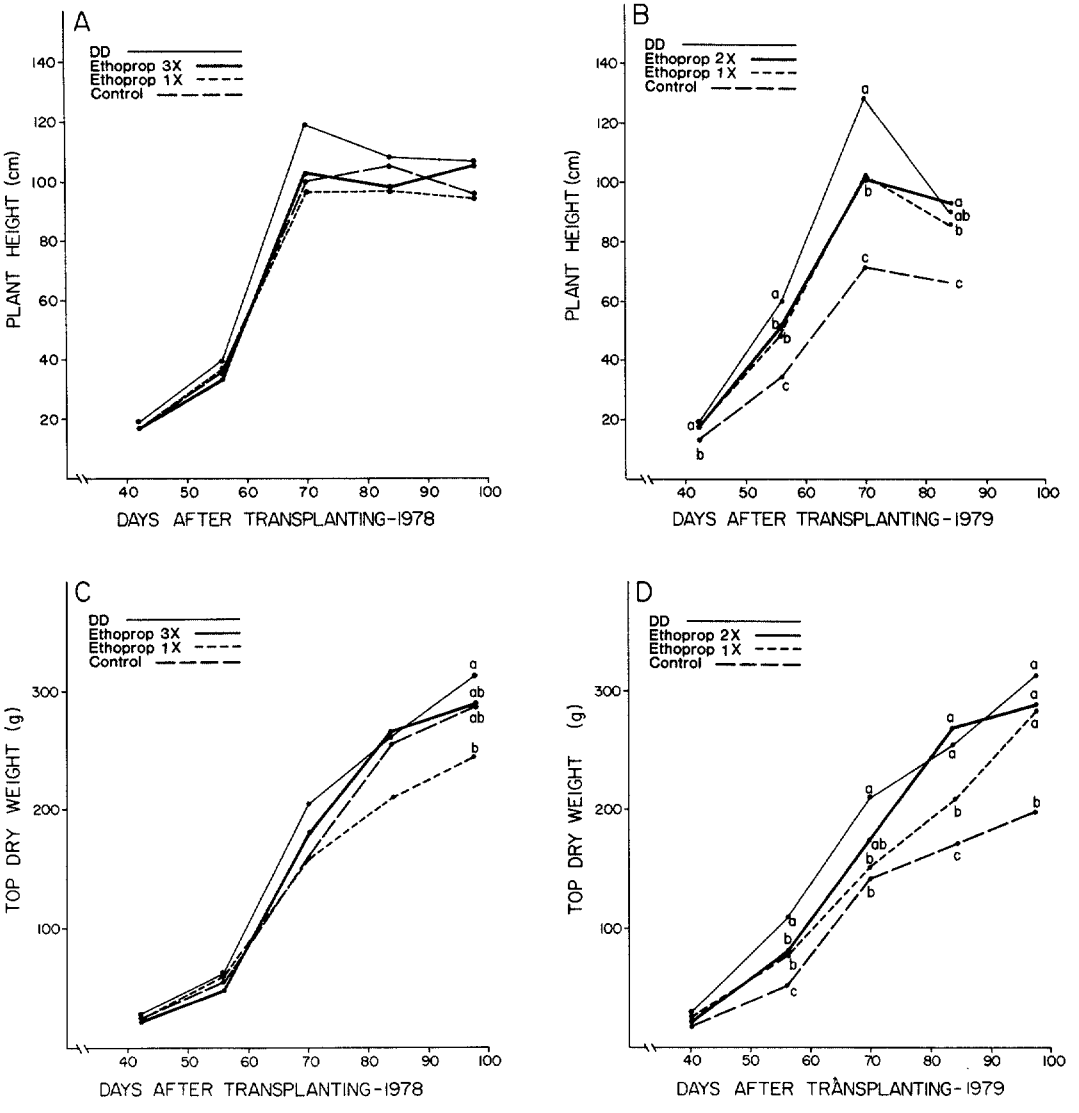


FIG. 2. Influence of DD and ethoprop on tobacco plant growth in soil infested with *Meloidogyne javanica*. A, B) Tobacco plant height (cm) in 1978 and 1979. C, D) Tobacco plant top dry weights (g) in 1978 and 1979. Points on the same date followed by the same letter are not different ($P \leq 0.05$) according to Duncan's multiple-range test. See legend in Fig. 1 for rates of nematicide applied.

weights occurred at all sampling dates after 42 days (Fig. 2D). Highest cumulative whole plant dry weights were found in plants grown in DD treated soil, followed by those in the 18 kg a.i./ha ethoprop, 9 kg a.i./ha ethoprop, and control plots.

In 1978, plants grown in soil treated with DD produced higher cured leaf yields than plants in the other treatments (Table 1). Yield of tobacco from the 27 kg a.i./ha ethoprop treatment was higher than in the 9 kg a.i./ha ethoprop or in control plots, while yield differences were not found between the 9 kg a.i./ha ethoprop and control plots. In 1979, plants grown in soil treated with DD produced the highest tobacco yields but no higher than those in the 18 kg a.i./ha ethoprop treated plots. Yields of plants in the 9 and 18 kg a.i./ha ethoprop treatments were similar and higher than yields from the control plots.

Linear correlation coefficients between populations of *M. javanica* and cured leaf yield were significant 70 and 84 days after

TABLE 1. Yield of cured tobacco from plants grown in soil infested with *Meloidogyne javanica* after treatment from two nematicides.

| Treatment | kg a.i./ha* | Yield in kg/ha 1978 | Yield in kg/ha 1979 |
|---|---|---|---|
| DD | 187 | 3,489 a† | 3,203 a |
| Ethoprop | 27 | 3,019 b | |
| Ethoprop | 18 | | 2,975 ab |
| Ethoprop | 9 | 2,535 c | 2,891 b |
| Control | | 2,451 c | 2,306 c |

* DD rate given in liters/ha.

† Column means followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple-range test.

TABLE 2. Linear correlation coefficients relating *Meloidogyne javanica* numbers and root gall index ratings to cured leaf yield of tobacco.

| Days after transplanting | Nematode numbers* | Root gall index† |
|---|---|---|
| 1978 | | |
| 42 | −0.09‡ | |
| 56 | −0.39 | −0.67 |
| 70 | −0.75 | −0.67 |
| 84 | −0.71 | −0.37 |
| 98 | | −0.29 |
| 1979 | | |
| 28 | | −0.51 |
| 42 | | −0.79 |
| 56 | −0.70 | −0.84 |
| 70 | −0.78 | −0.78 |
| 84 | −0.52 | −0.83 |
| 98 | −0.72 | −0.83 |
| 119 | −0.61 | −0.57 |

* Juveniles extracted from 250 $cm^3$ soil in 1978; juveniles and eggs from 250 $cm^3$ soil in 1979.

† Root gall indices based on a 0–4 scale from two plants in each plot.

‡ Negative correlation coefficients 0.01–0.40 are nonsignificant; 0.41–0.51 are significant at $P \leq 0.05$; >0.51 are significant at $P \leq 0.01$.

transplanting in 1978 and at all sampling dates after 42 days in 1979 (Table 2). Significant correlations between root-gall indices and cured leaf yield occurred at 56 and 70 days in 1978 and at all sampling dates in 1979.

## DISCUSSION

Although differing in magnitude, similar trends in plant damage and nematode populations were observed in 1978 and 1979. In both years, a nearly season-long increase in *M. javanica* populations was observed as opposed to the populations reaching self-limiting levels earlier. As a result, significant positive correlations between nematode numbers and plant yield were found throughout the latter part of the tobacco season, agreeing with results of others (3,4). Correlation coefficients between root-gall indices and leaf yields were similar to those of *M. javanica* numbers and leaf yield. In addition, while only two plants were sacrificed for root galling estimates from each research plot on each sampling date, significant differences in root galling were observed among treatments. Thus, the present studies indicate that root-gall indices may provide an alternative to the time-consuming tasks of sampling soil and nematode extraction in nematicide tests (9,18). Whether using root-gall indices or nematode numbers, time of sampling is the most critical component for differentiating among treatments (3). The times for soil and root-gall index sampling for highest correlation with yield were different in 1978 but similar in 1979. Since conditions in every field vary, problems arise concerning the correct sampling time for root gall indexing or estimating nematode populations. Sampling at 70 days after planting, however, appeared satisfactory in these tests.

Tobacco growth may be affected by *M. javanica* at any stage of plant development and morphological expressions of damage vary with Pi and environmental conditions. In these tests, plant height, stem diameter, top dry weight, and leaf yield varied in sensitivity to nematode damage and the time of damage expression. In 1978, treatments did not influence plant height or stem diameter but cured leaf yield was affected. Top dry weight, however, was different among treatments only at the 98 day sampling, suggesting damage occurred predominately late in the season. In 1979, higher initial nematode numbers caused early significant differences in top dry weight, whereas plant height and stem diameters were less affected. Therefore, the most sensitive measures of plant damage by *M. javanica* were cured leaf weights and top dry weights, followed by plant heights and stem diameters. Leaf area and leaf thickness might also be affected in *M. javanica*-infected tobacco and perhaps should be measured in the future.

In both years, plants grown in soil treat-

ed with DD produced highest leaf yield followed by the 18 or 27 kg a.i./ha ethoprop rates, the 9 kg a.i./ha ethoprop rate, and the control. Performance of the 9 kg a.i./ha ethoprop rate proved erratic. These data are similar to other tests with *M. javanica* in Florida tobacco (5,14) and support the contention that use of ethoprop at 9 kg a.i./ha is not as effective as the application of DD to manage *M. javanica* in Florida. In fact, studies indicate that other nonfumigant nematicides are less consistent than fumigants in controlling dense populations of *Meloidogyne* spp. in flue-cured tobacco (5,16).

Although the high rate of ethoprop (27 kg a.i./ha) showed no visible phytotoxicity in 1978, it may have caused some reduction in plant growth. Nematode population and root galling data indicated ethoprop at 27 kg a.i./ha gave good control of *M. javanica,* but cured leaf yield was lower than where DD was applied. Consequently, ethoprop at 18 kg a.i./ha was used in 1979. The higher rates of ethoprop (18 and 27 kg a.i./ha), however, provided good control of *M. javanica,* and these rates should be tested further.

## Literature Cited

1. Arens, M. L., and J. R. Rich. 1981. Yield response and injury levels of *Meloidogyne incognita* and *M. javanica* on the susceptible tobacco 'McNair 944.' Journal of Nematology 13:196–201.

2. Arens, M. L., J. R. Rich, and D. W. Dickson. 1981. Comparative studies on root invasion, root galling, and fecundity of three *Meloidogyne* spp. on a susceptible tobacco cultivar. Journal of Nematology 13: 201–205.

3. Barker, K. R., F. A. Todd, W. W. Shane, and L. A. Nelson. 1981. Interrelationships of *Meloidogyne* spp. with flue-cured tobacco. Journal of Nematology 13:67–79.

4. Ferris, H. 1974. Correlation of tobacco yield, value, and root-knot index with early-to-midseason and postharvest *Meloidogyne* population densities. Journal of Nematology 6:75–81.

5. Garcia, R., and J. R. Rich. 1983. Efficacy of selected fumigant and nonfumigant nematicides to control *Meloidogyne javanica* in Florida tobacco. Nematropica 13:125–134.

6. Graham, T. W. 1961. Responses of tobacco breeding lines to three species of root-knot nematodes in greenhouse tests. Plant Disease Reporter 45: 692–695.

7. Hussey, R. S., and K. R. Barker. 1979. A comparison of methods of collecting inocula of *Meloidogyne* spp., including a new technique. Plant Disease Reporter 57:1025–1028.

8. Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes in soil. Plant Disease Reporter 48:692.

9. Johnson, A. W. 1974. Relative efficacy of selected nonvolative nematicides for control of root-knot nematodes in flue-cured tobacco. Tobacco Science 18:132–133.

10. Kucharek, T. A. 1981. Tobacco disease losses in Florida. P. 11 *in* Report of the tobacco disease loss evaluation committee of the Tobacco Disease Council. 30th Tobacco Worker's Conference, Williamsburg, Va.

11. Loh, C. L., and C. R. Miller. 1968. Effects of *Meloidogyne javanica* (Treub.) Chitwood, *M. incognita* (Kofoid & White) Chitwood, and *Phytophthora parasitica* Dast. var. Nicotianae (Breda de Hann) Tucker on varieties of tobacco resistant to blackshank and root-knot. Proceedings of the Soil and Crop Science Society of Florida 28:266–275.

12. Lucas, G. B. 1975. Diseases of tobacco, 3rd ed. Raleigh, North Carolina: Biological Consulting Assoc.

13. Milne, D. L. 1972. Nematodes of tobacco. *In* J. M. Webster, ed. Economic nematology. New York: Academic Press.

14. Nordmeyer, D., J. R. Rich, and D. W. Dickson. 1982. Effects of ethoprop, carbofuran, and aldicarb on flue-cured tobacco infected with three species of *Meloidogyne.* Nematropica 12:199–204.

15. Paddock, R. G., and J. W. Meagher. 1973. Effects of tobacco crop disposal methods and soil fumigation on control of root-knot nematode (*Meloidogyne javanica*) in north-eastern Victoria. Australian Journal of Experimental Agriculture and Animal Husbandry 13:108–122.

16. Powell, N. T. 1982. Disease control practices. Pp. 48–79 *in* 1983 Tobacco Information. North Carolina Extension Service Bulletin AG-187.

17. Rich, J. R., and N. C. Schenck. 1979. Survey of North Florida flue-cured fields for root-knot nematodes and vesicular-arbuscular mycorrhizal fungi. Plant Disease Reporter 63:952–955.

18. Sasser, J. N., T. L. Kirkpatrick, and R. A. Dybas. 1982. Efficacy of avermectins for root-knot control in tobacco. Plant Disease 66:691–693.

19. Schwepperhauser, M. A. 1975. Source of *Nicotiana tabacum* resistance to *Meloidogyne javanica.* Tobacco International 177:40–42.