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Growth of Selected Woody Ornamentals in the Field Following Inoculation with Root-Knot Nematodes

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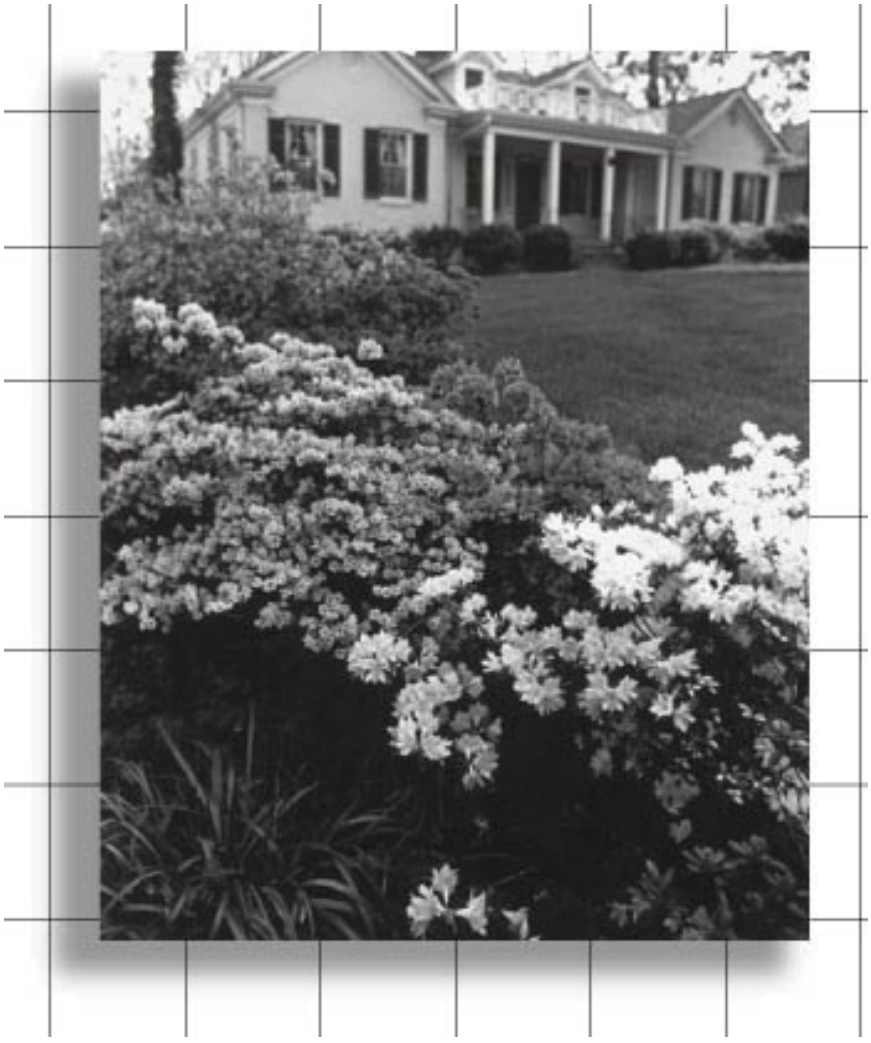

Conversion Table

U.S. Abbr.	Unit	Approximate Metric Equivalent
	Length	
mi	mile	1.609 kilometers
yd	yard	0.9144 meters
ft *or* '	foot	30.48 centimeters
in *or* "	inch	2.54 centimeters
	Area	
sq mi *or* mi^2	square mile	2.59 square kilometers
acre	acre	0.405 hectares *or* 4047 square meters
sq ft *or* ft^2	square foot	0.093 square meters
	Volume/Capacity	
gal	gallon	3.785 liters
qt	quart	0.946 liters
pt	pint	0.473 liters
fl oz	fluid ounce	29.573 milliliters or 28.416 cubic centimeters
bu	bushel	35.238 liters
cu ft *or* ft^3	cubic foot	0.028 cubic meters
	Mass/Weight	
ton	ton	0.907 metric ton
lb	pound	0.453 kilogram
oz	ounce	28.349 grams

Metric Abbr.	Unit	Approximate U.S. Equivalent
	Length	
km	kilometer	0.62 mile
m	meter	39.37 inches *or* 1.09 yards
cm	centimeter	0.39 inch
mm	millimeter	0.04 inch
	Area	
ha	hectare	2.47 acres
	Volume/Capacity	
liter	liter	61.02 cubic inches *or* 1.057 quarts
ml	milliliter	0.06 cubic inch *or* 0.034 fluid ounce
cc	cubic centimeter	0.061 cubic inch *or* 0.035 fluid ounce
	Mass/Weight	
MT	metric ton	1.1 tons
kg	kilogram	2.205 pounds
g	gram	0.035 ounce
mg	milligram	3.5×10^{-5} ounce

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Introduction

Plant parasitic nematodes feeding on roots of susceptible plants can result in stunted growth, chlorotic leaves, disfigured roots or, in some instances, even plant death. Nematodes injure root systems by disrupting the root anatomy, and hence the metabolic functions necessary for sustained growth. Frequently, these injuries or wounds also provide entryways for specific soil-inhabiting pathogenic bacteria and fungi.

Nematode populations commonly are highest in sandy or sandy-loam soil during the warmer seasons of the year, but many survive in the colder regions and in soils with higher clay contents, such as Piedmont regions of the southeastern United States.

Nematodes parasitize a variety of perennials and annuals. Losses to crops often are judged to be in the range of 10% (Bertrand, 1995), but estimates for losses to ornamental plants are more difficult to ascertain and may be lacking entirely for a specific woody landscape species. Lack of such information is the result of several factors: 1) There has been a greater demand for research on nematode effects on crops; 2) A longer time is required to conduct studies with woody ornamentals; and 3) The great diversity of horticultural landscape species and cultivars produced by the industry.

Regardless of the plant species, the most destructive and widespread nematodes are root-knot nematodes, which belong to the genus *Meloidogyne* (Society of Nematology, 1984). There are at least four species present in Georgia (Powell, 1990). The predominant root-knot species are *M. incognita* (Kofoid and White) Chitwood and *M. arenaria* (Neal).

From the 1960s to the early 1980s, the predominant method for controlling nematodes on row crops was with nematicides, although sanitation, rotation, and plant resistance have always been part of the total control package recommended by the Cooperative Extension Service, University of Georgia, College of Agricultural and Environmental Sciences (Motsinger, et al, 1981). In the late 1980s and now in the 1990s, the public's environmental awareness has increased considerably, and their concerns regarding continued pesticide applications have stimulated researchers to study alternative measures to keep plants healthy.

The objective of these studies was to examine a group of woody ornamentals for their susceptibility to root-knot nematodes and determine if these nematodes adversely affect the growth of these plants over several growing seasons under field conditions. Ornamentals that are either nonhosts or tolerant of nematodes can be suggested for landscaping. The root-knot nematode species selected were *M. incognita* race 3 and *M. arenaria* race 2.

Literature Review

Surveys of plant parasitic nematodes on woody ornamentals were common 20 to 30 years ago (Barker, et al, 1979; Birchfield, et al, 1978; Davis and Jenkins, 1960; Haasis, et al, 1961; Mai, et al, 1960; Springer, 1964; Stessel, 1961; Wilson and Walker, 1961). Although root-knot nematodes were not always the most frequently found parasitic nematode, their mere presence on so many different plant species led to research on possible chemical controls because of the potential for plant damage (Johnson and Feldmesser, 1987; Harlan and Jenkins, 1967; Heald and Jenkins, 1964; Miller and Perry, 1965; Taylor and Sasser, 1978; Walker and Wilson, 1962). Few chemicals were even available for pre- or post-plant treatments (Johnson and Perry, 1965). Now there are even fewer because of environmental and safety concerns. Nematologists, while not abandoning the exploration of newer chemistries or application techniques (Johnson and Feldmesser, 1987; Wright, 1981), have met this challenge by studying the biology, pathogenicity, and reproduction of parasitic nematodes in greater detail on various plants, including woody ornamentals. Quantifying the severity of damage by nematodes on woody perennials is a challenge. Yet answers to these and similar questions are required to develop the best possible disease control management strategies for an expanding green industry (Dunn, 1996).

A wide variety of woody ornamental species are produced in the southeastern United States, and information is available **(Table 1, p. 10)** on reaction of some to root-knot nematodes. For example, the decline of boxwood (*Buxus* sp.) because of nematodes has been known for a long time (Lehman, 1984). Root-knot nematodes were discovered on gardenia more than a century ago (Lehman, 1984), causing disruption of the cortical root tissue, similar to that in crop plants (Davis and Jenkins, 1960), resulting in decline of plant vigor. Additional woody plant taxa have been evaluated more recently for their sensitivity to root-knot nematodes by inoculation with given populations of eggs or juveniles (Bernard and Witte, 1987; McSorley and Dunn, 1990).

Holly species are prevalent in southeastern landscapes, and certain ones are known hosts for root-knot nematodes (Aycock, et al, 1976; Barker, et al, 1979; Benson and Barker, 1982; Bernard, et al, 1994; Heald, 1967; Stokes, 1982). For example, the Japanese hollies *(Ilex crenata)* are highly susceptible to root-knot *(M. arenaria, M. hapla, M. incognita, M. javanica,* and *M. incognita acrita),* whereas Chinese holly *(I. cornuta)* and dwarf Yaupon holly *(I. vomitoria)* are tolerant (Barker, et al, 1979). *Meloidogyne hapla* did not cause galling on roots of *Ilex* x *attenuata,* Foster #2, *I. crenata* 'Hetzii' or *I. cornuta* x *aquifolium* 'Nellie R. Stevens' (Bernard and Witte, 1987). In a comparison of root-galling by two isolates of *M. hapla* and one of *M. incognita* on 17 cultivars of holly, *M. incognita* produced galls on all cultivars, but galling by *M. hapla* varied on seven cultivars, depending on the source of the nematode isolate (Bernard, et al, 1994). Variability in virulence of nematode isolates may be quite common, thereby complicating management practices for different regions.

Although 1,000 root-knot juveniles per 4 in. dia. pot on *Ilex* species caused growth reduction and loss in plant weights (Heald, 1967), this may not always occur under field conditions (Walker, unpublished). Variation in population densities, soil types, and environmental factors all can influence the results. *Meloidogyne arenaria, M. incognita,* and *M. javanica* all cause root-galling, but fresh shoot or root weight of several woody ornamental species was not reduced (McSorley and Dunn, 1990).

The relationships between nematode population densities and plant growth or yield has been studied more extensively with crop plants than with ornamentals (Barker and Olthop, 1976; Starr, 1989). Frequently, greater plant growth occurs with low populations of nematodes than in the absence of nematodes.

Materials and Methods

All woody plants used in these studies were obtained as liners from commercial nurseries or propagated as cuttings under mist from December, 1991, to March, 1992. After appropriate growth, plants or rooted cuttings were transplanted into plastic pots (4 or 8 in. dia.) containing a steamed soil-mix (2 parts soil, 1 part Fafard #3 or Metro-mix 300 [Fafard, Anderson, S.C.; Scotts, Marysville, Ohio]). The soil, from a field at the Georgia Station, Bledsoe Farm, Pike County, Georgia, was classified as a sandy-loam, Cecil Series, clayey, kaolinitac, Thermic, Typic Hapuladalt consisting of 70% sand, 12% silt, 18% clay, and pH 5.1. This soil was chosen as typical for the region where landscapers may be planting woody ornamentals in residential developments.

The 12 woody ornamental species included in these investigations were: *Abelia* x *grandiflora* (Andrè) Rehder, *Buxus semperverins* L., *Camellia sasanqua* Thunb (five cultivars), *Cedrus deodara* (D. Don) G. Don, *Cephalotaxus harringtonia* (Forbes) K. Koch, X *Cupressocyparis leylandi, Lagerstroemia indica* L. (two cultivars), *Ligustrum lucidum* Aiton, *Ligustrum sinense* Lour., *Rhododendron* spp. (six azalea cultivars), *Viburnum japonicum* L., *Viburnum plicatum* Thumb. var. *tomentosum* Miq.

Potted plants were grouped by species in a polyethylene covered house with temperatures ranging from 60 degrees to 90 degrees F. Plants were watered daily and fertilized with Osmocote (14-14-14) in the spring and fall using 0.2g/in.^{2} soil surface. Six months after transplanting, the plants were infested with root-knot nematodes *(M. arenaria* or *M. incognita)* by adding 0, 8, 16, and 50 nematode eggs/in.^{3} soil to each container. In several instances, greater egg densities were included. Each infestation treatment was replicated five or six times within each plant species. The eggs were obtained by the sodium hypochlorite method (Hussey and Barker, 1973) from the galled roots of coleus (*Coleus blumei*

Benth.) for *M. arenaria,* or eggplant (*Solanum melongena* L. cv Black Beauty) for *M. incognita.* Egg suspensions were divided among four pre-punched holes 2 in. deep around the base of each plant. Holes were closed with soil after inoculation.

To allow for nematode establishment, all inoculated and non-infested plants remained in the polyhouse from 6 to 12 months before "potting on" into larger containers, which were moved to the field. Each plant container was assigned a number according to the treatment [egg density], and the containers were set within a larger container buried in the soil (pot-in-pot). Containers were arranged in a completely random design. There were 36 containers on 50 in. centers in each of 10 rows of the 1993 plot and 40 containers in each of 11 rows in the 1994 plot. The overall dimensions for 1993 and 1994 plots were 85 x 145 ft. and 89 x 168 ft., respectively. Plots were irrigated during dry periods, and weed/grass control in and around containers was obtained by mowing and with selective herbicide applications of Roundup and Poast®.

To assay for the presence and survival of root-knot nematodes after plants were in the field, four 1-in. dia soil cores were removed periodically from around each plant. Each soil sample was mixed thoroughly and transferred to Styrofoam cups (20 $in.^3$). A seedling tomato ('Rutgers') was transplanted into each cup as a bioassay for the presence of nematodes. The tomato plants grew for six to eight weeks in a greenhouse before roots were washed and rated for root-galling. The rating system was 0 to 5 with 0 = none, 1 = 1-2, 2 = 3-10, 3 = 11-30, 4 = 31-99, 5 = >100 galls per plant.

Measurements of woody plant heights and the average of plant height plus width were taken on each plant at intervals over two years. Any significant differences in these values within species would be interpreted as growth responses to the nematode inoculum densities.

Following two years' growth, all plants were severed at ground level and the shoots dried at 130 degrees for one month to obtain dry weights. The 1993 planting was harvested on September 27, 1995, and the 1994 planting on October 28-29, 1996. Sprouting from severed roots was noted the spring following harvest. Roots of harvested plants were purposely not examined for galls to allow for additional studies on nematode survival.

All growth data were analyzed by General Linear Model Procedure (GLM) and mean values for the different parameters were subject to the "T" test to determine least significant differences (LSD) between mean values at $P \leq 0.05$.

Results

The results of these investigations will be discussed with the narrative based on those parameters for which the F value was significant at $P \leq 0.05$ by the GLM.

1993: Heights, the averages of height plus width, and dry weights of variegated privet *(Ligustrum sinensis)* were not affected by inoculations with either 16 or 100 eggs/$in.^3$ of *M. arenaria* or *M. incognita* **(Table 2, p. 11)**. Both nematodes caused heavy galling on tomato assay plants in soil removed before and after harvest of the privet, indicating that nematodes reproduced on this woody ornamental during the two years in the field. Similarly, neither of these root-knot nematode species affected the heights or weights of wax privet *(L. lucidum)* during two years. Although the gall-indices on tomato assays from wax privet soil were less than from those from variegated privet, there were sufficient nematodes present in the soil nine months after harvest to cause galling on tomato (data not reported).

Heights of inoculated 'Natchez' crape myrtle *(Lagerstroemia indica)* were less than the non-infested plants early in the study, but final heights and dry weights were not different than controls. Modest root-galling occurred on tomato grown in crape myrtle soil (rating of 2.4). 'Tuscarora' crape myrtle was not affected by either densities of root-knot nematodes and, in general, the tomato assay plants had a lower gall-rating (0.5-1.6) than those from 'Natchez,' suggesting lower nematode reproduction may have occurred on this cultivar **(Table 3, p. 12)**.

Viburnum japonicum, obtained originally as *V. macrophyllum,* responded differently to the two root-knot nematode species. No decrease in growth resulted from infestation with *M. incognita,* but some growth stimulation occurred from *M. arenaria* inoculations. Although the mean dry weights of *M. arenaria* inoculated plants exceeded those of non-inoculated plants at harvest, the differences were not

significant (P = 0.05). Galling of tomato roots was not high at any sampling date, suggesting that nematode reproduction was relatively low, and few nematodes might be recovered from this viburnum.

Viburnum plicatum tomentosum height was less than the controls soon after inoculation with *M. incognita;* however, dry weights between inoculated and non-inoculated plants did not differ at harvest. Tomato gall indices were not excessively high, indicating this viburnum was similar to *V. japonicum* in host reaction.

Only data for those plants whose soil produced root-galls on tomato assay plants are provided **(Table 3, p. 12)**. Five *Camellia sasanqua* cultivars, infested with two densities (16 and 100 eggs/in.^{3}) of both root-knot nematode species in October, 1992, and moved to the field in 1993, failed to grow well enough to be considered in the final evaluation. By July, 1996, 67% of the non-infested plants were dead. Only 2 of 61 soil samples removed for root-knot assays yielded root galls on tomato in 1996.

The regrowth or sprouting from severed roots of crape myrtle and *V. plicatum tomentosum* harvested in 1995 was readily apparent in 1996 and 1997. Notes were recorded in November, 1996, and a sprouting score was assigned to each living plant **(Table 4, p. 12)**. The percentage sprouting from root-knot invested crape myrtle and viburnum, based on six replications, exceeded the sprouting of the non-infested plants. None of the variegated privet or other viburnum resprouted from severed roots.

1994: The growth of *Cupressocyparis leylandi* (Leyland cypress), *Cedus deodara* (Deodar cedar), and *Taxodium distichum* (baldcypress) was not adversely affected by either root-knot species at these inoculum densities. *Cephalotaxus harringtonia* (plume yew) height was not affected by these nematodes during its survival period in the polyhouse or for one year in the field; however, most plume yew plants died after one year, apparently because of environmental conditions in the field. No root-galls were produced on any tomato plants grown in soil from any of the above plant species, indicating all to be nonhosts. No new shoots grew from the severed roots of any of these plants.

The *Abelia* x *grandifolia* height plus width value was affected slightly by *M. incognita*, but not by infestation with *M. arenaria*. The dry weights of infested abelia exceeded the controls at several *M. incognita* densities **(Table 5, p. 13)**. The root-gall indices on tomato assays indicated that reproduction of both nematode species occurred on abelia **(Table 6, p. 14)** during the experimental period. By the spring of 1997 (five months after harvest), abelia had sprouted from roots of all infested and non-infested plants.

The height plus width category of *Buxus sempervirens* infested with *M. arenaria* was variable, depending on the nematode density, yet this measurement did not vary with *Buxus* infested with *M. incognita.* Neither of the nematode species affected the dry weights of boxwood. Root-knot reproduction occurred, but was less on boxwood than on abelia, before and after the host plants were harvested **(Table 6, p. 14)**.

Azaleas cultivars did not grow well in this field location and, therefore, were excluded in the data analysis. Although five replicates of six cultivars were infested with 160 eggs/in.^{3} of *M. incognita* when moved to the field in 1994, 32 of 60 plants were dead by 1996.

Discussion

The woody ornamental species in these studies purposely were not inoculated with extremely high nematode egg densities, because one objective was to determine if populations would increase under soil/field conditions. Also, it often is suggested that low nematode populations frequently will stimulate plant growth, and this was an attempt to determine if this phenomenon would occur. If the growth of the various inoculated plants had been affected by the different densities of nematodes, a regression analysis of data would have been appropriate to demonstrate differences relative to initial populations.

Obviously, the plant species selected for these investigations are only a small number of those commonly grown in the landscape of the Piedmont region (middle Georgia). Other woody species may not respond similarly in the higher clay content soils of mid-Georgia. Results in the sandy Coastal Plain area of the state would be different. We chose those species where nematode-host relationship information might be lacking. For example, with increased plantings during the past decade of certain gymnosperms, such as Leyland cypress, it seemed appro-

priate to evaluate the response of such taxa to the root-knot nematodes.

The main difficulty with any extensive type field studies is the labor intensiveness required to establish and maintain the microplot (pot-in-pot) system. Nevertheless, plant growth was very satisfactory except for azalea, camellia, and plume yew.

Using a nematode infestation density designated on the basis of number of eggs per given volume allows for adjustment of numbers based on the volumes encountered with different-sized plant containers. This designation also permits easy comparisons with other research results if pot or container sizes are given.

Our results agree with other findings that *Abelia* x *grandifolia* and viburnum are hosts for root-knot nematodes and that gymnosperms generally are nonhosts (Bernard and Witte, 1987). Although differences in crape myrtle growth were not detected, reproduction of nematodes occurred, and these plants are considered hosts. Population buildup of either *M. arenaria* or *M. incognita* on *Buxus,* a known host, apparently did not occur as rapidly as on *Abelia* x *grandifolia*. *Buxus* often is injured severely by root-knot nematode in the landscape and other species, including *Pratylenchus penetrans,* the lesion nematode. Use of methyl bromide-treated field soil at transplanting certainly reduced the chances for contamination with other nematodes.

The impact of different nematode species in combination on ornamental plants is worthy of future consideration because the natural population is interspecific. However, until long-term impacts of single nematode populations under landscape conditions can be determined, the interspecific studies will have little meaning.

Summary

Twelve species or cultivars of woody ornamentals were infested with different egg densities of *Meloidogyne arenaria* or *M. incognita* to determine if growth would be affected over two years in the field, and if nematode reproduction would occur on these plants.

Height and height plus width growth measurements or plant dry weights seldom were affected by the root-knot nematodes, although nematode reproduction did take place on certain ornamentals over two years, as indicated by root-gall formation on tomato assay plants grown in soil removed from all ornamentals. *Abelia* x *grandifolia* was the only ornamental species where the final dry weights were affected by *M. incognita* infestation.

The results indicate the following woody taxa are hosts for both *M. arenaria* and *M. incognita: Abelia* x *grandifolia, Buxus semperverins, Lagerstroemea indica* cultivars 'Natchez' and 'Tuscarora,' *Ligustrum lucidum, Ligustrum sinensis, Viburnum japonicum,* and *Viburnum plicatum tomentosum.*

The following taxa are considered nonhosts for these two root-knot nematode species, as no root-galls were detected on tomato assays after repeated soil samplings: *Cedrus deodara, Cupressocyparis leylandi,* and *Taxodium distichum.* The host status of *Cepholotaxus harringtonia,* camellia, and azalea cultivars could not be determined in this study because a sufficient number of plants did not survive.

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Literature Cited

Aycock, R., K.R. Barker, and D.M. Benson. 1976. Susceptibility of Japanese holly to *Criconemoides xenoplax, Tylenchorhynchus claytoni,* and certain other plant-parasitic nematodes. *Journal of Nematology 8:* 26-31.

Barker, K.R., D.M. Benson, and R.K. Jones. 1979. Interactions of Burfordi, rotunda, and dwarf yaupon hollies and acuba with selected plant-parasitic nematodes. *Plant Disease Reporter 63:* 113-116.

Barker, K.R., and T.H.A. Olthof. 1976. Relationships between nematode population densities and crop responses. *Annual Review of Phytopathology 14:* 327-353.

Benson, D.M., and K.R. Barker. 1982. Susceptibility of Japanese boxwood, dwarf gardenia, Compacta (Japanese) holly, Spiny Greek and Blue Rug juniper, and nandina to four nematode species. *Plant Disease 66:* 1176-1179.

Bernard, E.C., and W.T. Witte. 1987. Parasitism of woody ornamentals by *Meloidogyne hapla. Annals of Applied Nematology 1:* 41-45.

Bernard, E.C., W.T. Witte, M.M. Dee, and P.L. Jennings. 1994. Parasitism of holly cultivars by three root-knot nematode isolates. *Holly Society Journal 12:* 12-17.

Bertrand, P.F. 1995. *1994 Georgia plant disease loss estimates.* Cooperative Extension Service, College of Agricultural and Environmental Sciences. The University of Georgia. Path 95-007. 11 p.

Birchfield, W., J.P. Hollis, and W.J. Martin. 1978. *A list of nematodes associated with some Louisiana plants.* Louisiana State University Agricultural Experimental Station. Tech. Bulletin 101. 22 p.

David, R.A., and W.R. Jenkins. 1960. Histopathology of gardenia (*Gardenia jasmoides* 'veitchii') infected with three species of *Meloidogyne*. *Nematologica 5:* 228-230.

Davis, R.A., and W.R. Jenkins. 1960. Nematodes associated with roses and the cytology and histology of rose roots parasitized by *Meloidogyne hapla, Xiphinema diversicaudatum,* and *Helicotylenchus nannus.* University of Maryland, Agricultural Experiment Station. Bulletin A-106. 16 p.

Dunn, R.A. 1996. *Nematode management for landscape ornamentals.* Florida Cooperative Extension Service, IFAS, University of Florida. Nematology Pointer No. 42. 10 p.

Haasis, F.A., J.C. Wells, and C.J. Nusbaum. 1961. Plant parasitic nematodes associated with decline of woody ornamentals in North Carolina and their control by soil treatment. *Plant Disease Reporter 45:* 491-496.

Harlan, D.P., and L. Jenkins. 1967. Elimination of root-knot nematodes from plants by chemical bare-root dips or soil drenches. *Plant Disease Reporter 51:* 103-107.

Heald, C.M., Jr., and W.R. Jenkins. 1964. Effects of DBCP on various species and varieties of woody ornamentals. *Plant Disease Reporter 48:* 499.

Heald, C.M. 1967. Pathogenicity of five root-knot nematode species on *Ilex crenata* 'Helleri.' *Plant Disease Reporter 51:* 581-583.

Hussey, R., and K.R. Barker. 1973. A comparison of methods of collecting inocula of *Meloidogyne* species including a new technique. *Plant Disease Reporter 57:* 1025-1028.

Johnson, H.N., and V.G. Perry. 1965. Elimination of nematodes from nursery plants by chemical bare-root dips. *Plant Disease Reporter 49:* 51-53.

Johnson, A.W., and J. Feldmesser. 1987. Nematicides – A historical review. Chapter 59. In, *Vistas on Nematology: A commemoration of the Twenty-fifth Anniversary of Society of Nematologists,* ed. J.A. Veech and D. Dickson. 509 p.

Lehman, P.S., and E.L. Barnard. 1982. *A root-knot nematode pathogenic to flowering dogwood* Cornus florida. Florida Department Agriculture & Consumer Services, Division of Plant Industry. Nematology Circular 84. 2 p.

Lehman, P.S. 1984. *Nematodes causing decline of boxwood.* Florida Department of Agriculture & Consumer Services, Division of Plant Industry. Nematology Circular 108. 2 p.

Lehman, P.S. 1984. *Nematodes which cause decline of gardenia.* Florida Department of Agriculture & Consumer Services, Division of Plant Industry. Nematology Circular No. 111. 2 p.

Mai, W.F., H.W. Crittenden, and W.R. Jenkins. 1960. *Distribution of stylet-bearing nematodes in Northeastern United States.* Bulletin 795. Rutgers: New Jersey Agricultural Experiment Station. 62 p.

McSorley, R., and R.A. Dunn. 1990. Infection of five species of landscape ornamentals by root-knot nematodes (*Meloidogyne* spp.). *Proceedings of the Soil Science Society of Florida 49:* 227-230.

Miller, H.N., and V.G. Perry. 1965. Elimination of nematodes from nursery plants by chemical bare-root dips. *Plant Disease Reporter 49:* 51-53.

Motsinger, R.E., N.E. McGlohon, S.S. Thompson, J.L. Crawford, J.D. Gay, E.H. Moody, Sr., J.S. Arnett, and P.F. Bertrand. 1981. *Nematodes: Biology and Control.* Cooperative Extension Service. The University of Georgia. Bulletin 652. 25 p.

Powell, W.M. 1990. *Plant susceptibility to major nematodes in Georgia. A Guide to Planning Crop Rotation.* Cooperative Extension Service. The University of Georgia. Bulletin 904. 15 p.

Society of Nematology Geographical Distribution Committee. 1984. *Distribution of Plant-Parasitic Nematode Species in North America.* Society of Nematologists. 205 p.

Springer, J.K. 1964. *Nematodes associated with plants in cultivated woody plant nurseries and uncultivated woodland areas in New Jersey.* New Jersey Department of Agriculture. Circular 429. 40 p.

Starr, J.L. 1989. Population dynamics of root-knot nematodes. In, *Variability and Population Dynamics of Root-Knot and Cyst Nematodes in the Southern Region of the United States.* Southern Regional Technical Committee S-154. Southern Cooperative Series Bulletin 336. 21 p.

Stessel, G.J. 1961. *Nematodes of woody plants in Rhode Island.* University of Rhode Island, Agricultural Experiment Station. Bulletin 360. 19 p.

Stokes, D.E. 1982. *The effects of root-knot nematodes,* Meloidogyne *spp. on Japanese holly.* Florida Department of Agriculture & Consumer Services, Division of Plant Industry. Nematology Circular No. 83. 2 p.

Taylor, A.L., and J.N. Sasser. 1978. Biology, Identification, and Control of Root-Knot Nematodes (*Meloidogyne* species). North Carolina State University Graphics, Raleigh, N.C. 111 p.

Walker, J.T., and D. Wilson. 1962. Treatment of propagating stock with chemicals at different temperatures for root-knot control. *Phytopathology 52:* 684-688.

Wilson, J.D., and J.T. Walker. 1961. *An inventory of stylet-bearing nematodes in Ohio.* Ohio Agricultural Experiment Station. Special Circular 97. 10 p.

Wright, D.J. 1981. Nematicides: Mode of action and new approaches to chemical control. pp. 421-449. In, *Plant Parasitic Nematodes, Vol. 3.* Eds. B.M. Zuckerman and R.A. Rohde. New York: Academic Press. 508 p.

Table 1. Presence (+) absence (-) or reports of both (±) root-galling and egg mass production (EM) on woody ornamentals exposed to *Meloidogyne* species, as reported from several sources.[1]

	***Meloidogyne* Species:**							
	arenaria		**hapla**		**incognita**		**javanica**	
Woody Ornamental Taxa	**Galls/EM**		**Galls/EM**		**Galls/EM**		**Galls/EM**	
Abelia grandiflora			+	good				
Acuba japonica	+							
Buxus microphylla	+				+			
Cornus florida	+		+	good	+			
Dracena marginata							+	good
Ficus benjamina							+	good
Gardenia jasmoides	+		+	good	+			
Hydrangea paniculata			+	good				
Ilex crenata	+		±	none	+	good	+	
I. cornuta	±	none	+		±	none	±	none
I. vomitoria	±		-					
Ligustrum sinense	+	poor						
Nandina domestica	+	poor	-					
Photinia x *fraseri*	±	none	+	good	-	none	-	none
Rosa spp	+							
Spiraea x *bumalda*			+	good				
Spiraea x *vanhouttei*			+	good				
Viburnum carlesii			+	good				
Aborvitae			-	none				
Azalea			-	none				
Dawn Redwood			-	none				
Euonymus			-	none				
Hemlock			-	none				
Japanese holly (*I. crenata* 'Hetzii')			-	none				
Juniper			-	none				
Magnolia			-	none				
Maple			-	none				
Pine			-	none				
Rhododendron			-	none				
Sandcherry			-	none				

[1] Bernard and Witte, 1987; Benson and Barker, 1982; Heald, 1967; Johnson, Ratcliffe and Freeman as cited by Lehman and Barnard, 1982; McSorley and Dunn, 1990.

Table 2. Mean plant heights, height plus width values at different dates and final shoot dry weights of woody ornamentals inoculated with either Meloidogyne arenaria (Ma) or M. incognita (Mi) at different egg populations (1993).

Plant	Root-knot Species	Density eggs/in.[3]	Ht. (in.)[1]			Ht. + Wd. ÷ 2 (in.)[1]			Shoot dry wt. (lb.)[1]
			12/92	7/93	10/93	5/94	3/95	8/95	
Ligustrum sinensis	Ma	0	24	23	28	----[2]	----	----	----
		16	27	26	33	34	41	54	2.7
		100	27	26	31	34	39	56	3.0
	Mi	0	28	28	31	33	37	53	2.9
		16	28	27	31	34	39	61	3.8
		100	27	27	30	32	37	62	3.6
Ligustrum lucidum	Ma	0	16	17	21	----[2]	----	----	----
		16	16	17	22	22	24	45	2.0
		100	17	17	22	25	31	47	2.2
	Mi	0	17	20	20	23	24	40	2.0
		16	14	15	18	21	24	43	1.9
		100	19	19	24	24	25	40	1.6
Lagerstroemea indica 'Natchez'	Ma	0	34	30 a	32 a	34	34	56	2.8
		8	27	23 b	25 b	30	34	57	3.1
		50	28	24 b	27 b	30	34	61	3.0
	Mi	0	31	25	30 a	35 a	38	60	3.3
		8	25	19	23 b	31 ab	35	58	2.6
		50	31	21	26 ab	29 b	34	53	2.5
Lagerstroemea indica 'Tuscarora'	Ma	0	28	23	24	26	24	47	1.4
		8	29	28	30	28	26	53	1.8
		50	36	26	29	30	29	54	1.8
	Mi	0	29	22	24	25	26	58	2.0
		8	29	21	24	27	25	60	2.4
		50	29	22	24	24	23	52	1.8
Viburnum japonicum	Ma	0	11	9	11	17	17	28 b	1.0
		8	11	10	13	18	19	35 a	1.4
		50	12	10	12	17	19	31 ab	1.1
	Mi	0	11	11	12	19	19	32	1.4
		8	12	12	13	19	23	35	1.9
		50	10	11	11	19	22	37	1.6
Viburnum plicatum tomentosum	Ma	0	17 a	17	18	23	22	43	1.6
		8	16 a	17	19	24	26	44	1.7
		50	13 b	13	15	22	22	39	1.2
	Mi	0	23	23 a	24 a	24 b	24 b	44	1.9
		8	22	24 a	25 a	27 a	26 a	45	1.9
		50	20	21 b	22 b	23 b	24 b	46	2.3

[1] Mean of six replicates. Letters associated with values only where differences were significant at P = 0.05.
[2] Plants not available.

Table 3. Root-gall indices on tomato (Rutgers) assay plants grown in soil from woody ornamentals previously infested with different egg densities of *Meloidogyne arenaria* (Ma) or *M. incognita* (Mi) in 1992 and transplanted to field in 1993.

		Mean Root-Gall Index[1]					
		Ma[2]			Mi[2]		
Plant/Common name	Density eggs/in.[3]	6/95	11/95	6/96	6/95	11/95	6/96
Ligustrum sinensis / Variegated privet	16	4.8	ND	3.8	5.0	2.5	3.5
	100	5.0	4.8	4.0	5.0	1.2	4.0
Ligustrum lucidum / Wax privet	16	0.8	ND	ND	2.2	ND	3.0
	100	1.0	1.5	4.0	3.3	1.7	2.2
Lagerstroemea indica / 'Natchez' crape myrtle	8	0.7	0	ND	1.0	0	ND
	50	0	0.3	ND	2.4	2.5	2.0
Lagerstroemea indica / 'Tuscarora' crape myrtle	8	1.6	0	ND	0	0	ND
	50	1.7	0	ND	0.5	0.7	ND
Viburnam japonicum / viburnum	8	0	0	ND	0.3	0	ND
	50	0.6	1.2	ND	1.7	0	ND
Viburnum plicatum tomentosum / Doublefile viburnum	8	0.7	0	ND	0.4	0.7	ND
	50	1.2	0.6	ND	0.4	ND	ND

[1] Mean based on six replications with root-gall index as follows: 0 = none; 1 = 1-2; 2 = 3-10; 3 = 11-30; 4 = 31-99; 5 = >100 galls/plant. ND = not determined.
[2] Dates sampled are five months before plant harvest, at time of plant harvest, and seven months after plant harvest, respectively.

Table 4. Sprouting from roots one year after harvest of shoots from *Meloidogyne arenaria* (Ma) and *M. incognita* (Mi) infested and non-infested plants transplanted in 1993.

Plant	Root-knot Nematode Species	Inoculation Density eggs/in.[3]	Sprouting %	Sprouting Score[1]
Ligustrum lucidum	Mi	0	0	0
		16	17	1
		100	0	0
Lagerstroemea indica 'Natchez'	Mi	0	50	4
		8	83	3
		50	83	3
	Ma	0	67	3
		8	83	3
		50	100	4
Lagerstroemea indica 'Tuscarora'	Mi	0	33	3
		8	83	2
		50	50	2
	Ma	0	50	2
		8	67	3
		50	83	3
Viburnum plicatum tomentosum	Mi	0	17	4
		8	17	4
		50	50	3
	Ma	0	33	2
		8	67	4
		50	50	4

1 Sprouting Score: 1 = small shoots only; 2 = fair growth; 3 = medium growth; 4 = good growth. Each plant rated separately and values averaged. Other plants in study did not sprout from roots.

Table 5. Mean height, height plus width average at different dates after infestation, and shoot dry weights of woody ornamentals following inoculation with different egg populations of *Meloidogyne arenaria* (Ma) and *M. incognita* (Mi) (1994).

Plant	Root-knot Species	Density eggs/in.[3]	Ht. (in.)[1]			Ht. + Wd. Avg.[1]				Shoot dry wt. (lb.)[1]
			7/93	4/94	8/94	3/95	8/95	4/96	7/96	
Abelia x *grandiflora*	Ma	0	24	----	38	33	36	35	43	0.7
		50	25	----	39	32	36	37	46	0.8
		100	28	----	41	34	32	34	43	0.5
	Mi	0	27 ab	----	45	35	32 b	35	48	0.7 c
		50	30 ab	----	36	34	38 ab	36	48	0.9 ab
		100	26 b	----	41	35	34 bc	35	48	0.8 abc
		320	34 a	----	45	37	41 a	42	48	1.0 a
		800	30 ab	----	41	35	37 ab	37	46	0.7 bc
Buxus semperverins	Ma	0	----	----	----	6 b	7 c	9 c	11 b	0.2
		80	----	----	----	8 a	10 a	13 a	14 a	0.3
		160	----	----	----	7 b	9 ab	12 ab	13 a	0.2
		320	----	----	----	6 b	7 bc	11 bc	11 b	0.2
	Mi	0	----	----	----	7	8	11	12	0.2
		80	----	----	----	7	10	13	14	0.3
		160	----	----	----	7	8	12	13	0.2
		320	----	----	----	7	8	12	13	0.2
Cedrus deodara	Ma	0	16	20	30	31	37	45	48	4.8
		80	19	21	30	30	39	43	47	4.2
		160	19	20	31	31	39	44	49	4.2
	Mi	0	17	20	32	33	41	45	51	4.1
		80	20	22	32	31	38	41	47	2.5
		160	18	20	28	26	37	45	50	4.2
Cephalotaxus harringtonia	Ma	0	----	19	22	21	9	----	----	----
		80	----	21	22	21	10	----	----	----
		160	----	19	22	18	14	----	----	----
	Mi	0	----	18	21	22	14	----	----	----
		80	----	18	22	19	11	----	----	----
		160	----	20	26	21	14	----	----	----
Cupressocyparis leylandi	Ma	0	10	19 a	31 ab	26	37	44	52	8.3
		80	10	16 b	29 b	23	37	47	57	9.6
		160	10	21 a	34 a	31	37	44	54	9.4
	Mi	0	10	17	28	24	32	45	52	8.7
		80	11	18	28	22	36	45	45	7.0
		160	11	50	32	26	37	42	50	7.1
Taxodium distichum	Ma	0	36	43	48	35	38	38	51	1.3
		80	36	43	48	33	33	37	43	1.1
		160	38	45	48	34	39	39	47	1.2
	Mi	0	35 b	41 b	46 a	28 b	31	36	45	1.2
		80	39 ab	42 ab	47 a	30 ab	34	35	40	0.9
		160	40 a	47 a	51 a	33 a	35	37	47	1.1

[1] Mean of five replications, except six for *Buxus*. Letters associated with values only where differences were significant at P = 0.05.
Dashes indicate no measurements.

Table 6. Mean gall indices on tomato (Rutgers) assay plants in soil before and after removal of woody ornamentals previously infested with *M. arenaria* (Ma) or *M. incognito* (Mi) and transplanted to field in 1994.

Plant	Nematode Species	Inoculation (eggs/in.^{3})	Root-Gall Index[1]	
			1 month before harvest: 9/16/96	5 months after harvest: 3/31/97
Abelia x *grandifolia*	Ma	50	1.6	0.0
		100	1.2	1.2
	Mi	50	0.8	1.0
		100	0.8	1.6
		330	3.6	2.4
		800	2.6	0.6
Buxus semperverins	Ma	80	0.3	0.3
		160	0.2	0.0
		320	0.2	0.0
	Mi	80	0.5	0.5
		160	0.0	0.0
		320	0.5	0.2

[1] Mean root-gall index based on five replications for *Abelia* and six for *Buxus* with ratings as follows: 0 = none; 1 = 1-2; 2 = 3-10; 3 = 11-30; 4 = 31-99; 5 = >100 galls/plant.

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