Disease Loss Assessment for Azalea, Rhododendron, and Japanese Holly in North Carolina Nurseries

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ABSTRACT

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Incidence of Phytophthora root rot of azalea caused by *Phytophthora cinnamomi* ranged from 1 to 19% with a mean of 16.9 ± 12.8% at 10 nurseries surveyed in North Carolina using a systematic sampling procedure. Tremendous variation in root rot incidence at the nurseries surveyed resulted in extremely variable population estimates for disease incidence. Incidence of Phytophthora dieback of hybrid rhododendron caused by *Phytophthora* spp. ranged from 0 to 12% at 10 nurseries surveyed, with a 6% incidence on a total plant population basis. Incidence of Phytophthora root rot of rhododendron caused by *Phytophthora* spp. ranged from 0 to 22%, with an incidence of 1.6% on a total plant population basis. Estimates for incidence of dieback and root rot of rhododendron were more reliable because the total plant population at each nursery was counted and scored for disease. Plant-parasitic nematodes, including *Macroposthonia* sp., *Meloidogyne* sp., and *Tylenchorhynchus* sp., were found in root and soil samples from field-grown plants at five Japanese holly nurseries surveyed. On a per plant basis, frequency of occurrence ranged from 4 to 100% at the nurseries depending on nematode species.

Crop loss caused by plant diseases is significant in the production of nursery stock. Better estimates of the loss due to disease are needed. In the past, disease estimators have observed plant diseases of a given crop over a geographic area and estimated the percentage of disease to calculate the loss. Unfortunately, this type of loss assessment may be biased because estimators often limit their visits to nurseries where diseases are known to be causing loss.

The need exists for unbiased estimates of crop loss due to plant disease for nursery production of woody ornamentals. In the southeastern United States, unbiased loss estimates for woody ornamentals are not available, as evidenced by a recent discussion session on crop losses at the International Congress for Plant Protection in Washington, DC (Benson, *unpublished*). Thus, there is a need for at least a pilot program to evaluate techniques, strategies, difficulties, and benefits of obtaining unbiased crop loss assessments for woody ornamentals under nursery production.

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Container-grown evergreen azaleas and hybrid rhododendrons and field-grown Japanese hollies (*Ilex crenata* Thunb.) were selected for estimating crop loss. Diseases assessed were Phytophthora root rot of azalea caused by *Phytophthora cinnamomi*, Phytophthora dieback and root rot of rhododendron caused by *Phytophthora* spp., and nematodes parasitic to Japanese holly. Azaleas and rhododendron infected with *Phytophthora* and Japanese holly infected with certain plant-parasitic nematodes (1,2) generally decline and die either at the nursery or after plants are transplanted to the landscape. In either case, disease incidence estimates are equivalent to disease loss estimates.

MATERIALS AND METHODS

Disease loss survey. A statewide inventory of nursery stock was used to develop lists of nurseries growing azalea, rhododendron, or Japanese hollies. Nursery inspectors of the North Carolina Department of Agriculture verified that nurseries on the list had at least 10,000 container-grown azaleas, at least 1,000 container-grown hybrid rhododendrons, or at least 0.4 ha of field-grown Japanese hollies. These criteria were considered minimal for nurseries typical of those producing azaleas, rhododendrons, or Japanese hollies. Nurseries were listed by geographic region of North Carolina so that 10 azalea and rhododendron and five Japanese holly nurseries could be systematically selected after the first nursery in each list was selected by random number (Fig. 1).

Azalea nurseries. A 10% disease loss estimate was used to determine the total number of samples needed from azalea nurseries. Based on a 2% standard error, a total of 1,000 samples should be taken. Hence about 100 samples were collected at each azalea nursery surveyed.

Azalea nurseries were surveyed using a systematic sampling procedure after the starting plant was selected by random number. The interval between samples was determined by the total number of azaleas in the nursery. Plant age and cultivar were recorded whenever possible. Roots and potting mix (100–200 cm^3) from each plant sampled were collected and stored in plastic bags in an insulated chest. Roots were washed free of adhering potting mix in the laboratory and plated on a modified pimaricin-penicillin-polymyxin medium containing pimaricin at 10 mg/L (7). Plates were examined microscopically for the presence of *P. cinnamomi* after 2 days at room temperature on the laboratory bench.

Rhododendron nurseries. All hybrid rhododendrons in the nurseries surveyed were examined and counted to determine total plants, cultivar name, plant age, number with typical root rot symptoms (8), and number with typical dieback symptoms (4). Thus, a population estimate for disease incidence was calculated for the rhododendron nurseries.

Japanese holly nurseries. In Japanese holly nurseries, a systematic sampling procedure similar to that used for azaleas was used. Soil and roots (at least 500 cm^3) from Japanese hollies were collected by probing approximately 10 times per plant to a depth of 15–25 cm and bulking the soil cores. In the laboratory, roots were separated from soil using a semiautomatic elutriator (5). Roots from each 500 cm^3 of soil were processed by the sodium hypochlorite method to dislodge eggs of *Meloidogyne* sp. for counting (6). Soil was collected on a 38-μm sieve and further processed with sucrose flotation to separate larvae and adults from soil for counting. All plant-parasitic nematodes were counted.

Time and cost estimates. A nursery survey log was kept to record travel time, survey time, and lab time for purposes of generating cost estimates for the survey.

RESULTS

Azalea nurseries. Incidence of Phytophthora root rot of azalea caused by *P.*

cinnamomi ranged from 1.0 to 19.2% at the nurseries surveyed (Table 1). On a nursery basis, disease incidence was 8.2 ± 6.4%. On a plant basis, disease incidence was 16.9 ± 12.8%. In calculating the standard error and disease incidence on a plant basis, a weighted average was used because a positive correlation between nursery size and disease incidence was observed. By this method, the total number of infected plants in the survey of 1,585,502 azaleas was almost 270,000 or 16.9%.

Table 1. Incidence of Phytophthora root rot of azalea caused by *Phytophthora cinnamomi* at 10 randomly selected nurseries in North Carolina

Nursery	Total plants	Plants surveyed	Percentage of infection
A	25,858	105	10.4
B	13,939	93	1.0
C	45,982	110	3.1
D	174,332	108	12.0
E	13,785	99	8.0
F	13,957	94	4.2
G	8,077	116	4.3
H	19,830	100	2.0
I	192,718	120	19.2
J	71,024	90	17.7

Table 2. Incidence of Phytophthora root rot of azalea caused by *Phytophthora cinnamomi* for the 13 most frequently sampled cultivars at 10 randomly selected nurseries in North Carolina

Cultivar	Plants sampled	Percentage of infection
Coral Bells	94	7.4
Delaware Valley White	16	12.5
Fashion	18	5.6
Formosa	74	6.7
George Tabor	37	2.7
Hershey Red	98	10.2
Hino Crimson	33	18.2
Hinodegiri	212	17.5
Pink Gumpo	26	0
Pink Ruffles	20	0
Redwing	17	29.4
Sherwood Red	16	12.5
Snow	76	18.4
White Gumpo	28	3.6

A modified chi-square test was performed to determine whether infected plants were clustered (Main, *unpublished*). Clustering was demonstrated in only two of 10 nurseries (F and G). The sample interval in the two nurseries was 150 and 70 plants, respectively. Because nursery blocks typically contain about 40 plants per meter, clustering of infected plants occurred within a distance of 18.8 and 10.5 m at nurseries F and G, respectively.

When data for cultivars were combined over nurseries, cultivars in the Kurume hybrid group (Coral Bells, Hershey Red, Hino Crimson, Hinodegiri, Sherwood Red, and Snow) had the greatest disease incidence (mean of 14%) and accounted for 51% of the plants sampled. On an individual cultivar basis, Redwing had 29.4% disease incidence, but only 17 plants were sampled. The Satsuki hybrids Pink Gumpo and White Gumpo averaged 1.8% incidence of root rot, one of the lowest measured (Table 2).

Table 3. Incidence of Phytophthora dieback and root rot of rhododendron at 10 randomly selected nurseries in North Carolina

Nursery	Plants surveyed	Dieback infection (%)	Root rot infection (%)
A	1,956	0	22.5
B	5,936	0.9	6.3
C	952	0.4	2.5
D	29,253	12.1	0
E	834	2.5	9.1
F	8,971	3.2	0.7
G	7,508	3.5	1.3
H	3,069	0.1	2.8
I	981	5.1	0.2
J	11,000	0.1	0

Rhododendron nurseries. Incidence of Phytophthora dieback and root rot was 2.8 ± 3.7% and 4.5 ± 7.0%, respectively, on a nursery basis (Table 3). Incidence of dieback and root rot ranged from 0 to 12.1% and 0 to 22.5%, respectively, at the individual nurseries. A total of 4,253 plants or 6.0% had dieback and 1,166 plants or 1.6% had root rot.

Of the 11 most widely grown cultivars, incidence of Phytophthora dieback was greatest in Chionoides White (17.9%), followed by Nova Zembla (12.7%) and Catawbiense Album (10.3%) (Table 4). The most resistant hybrids to dieback were PJM (0.6%), Scintillation (1.9%), and Roseum Elegans (2.2%). However, Scintillation had the greatest root rot incidence (2.8%).

Four *Phytophthora* spp. were isolated from a random sample of dieback tissue

Table 4. Incidence of Phytophthora dieback and root rot on 11 of the most widely grown rhododendron cultivars surveyed at 10 randomly selected nurseries in North Carolina

Cultivar	Plants surveyed	Dieback infection (%)	Root rot infection (%)
Album Novebum	404	8.1	0
Boursault	1,933	5.1	0.2
Chionoides White	1,697	17.9	0.4
Catawbiense Album	1,434	10.3	1.3
English Roseum	1,905	3.2	0
Nova Zembla	15,038	12.7	0.03
Roseum Elegans	10,725	2.2	1.1
Roseum Pink	1,276	8.5	0
Roseum Superbum	1,351	3.9	1.5
Scintillation	1,006	1.9	2.8
PJM	480	0.6	0.4

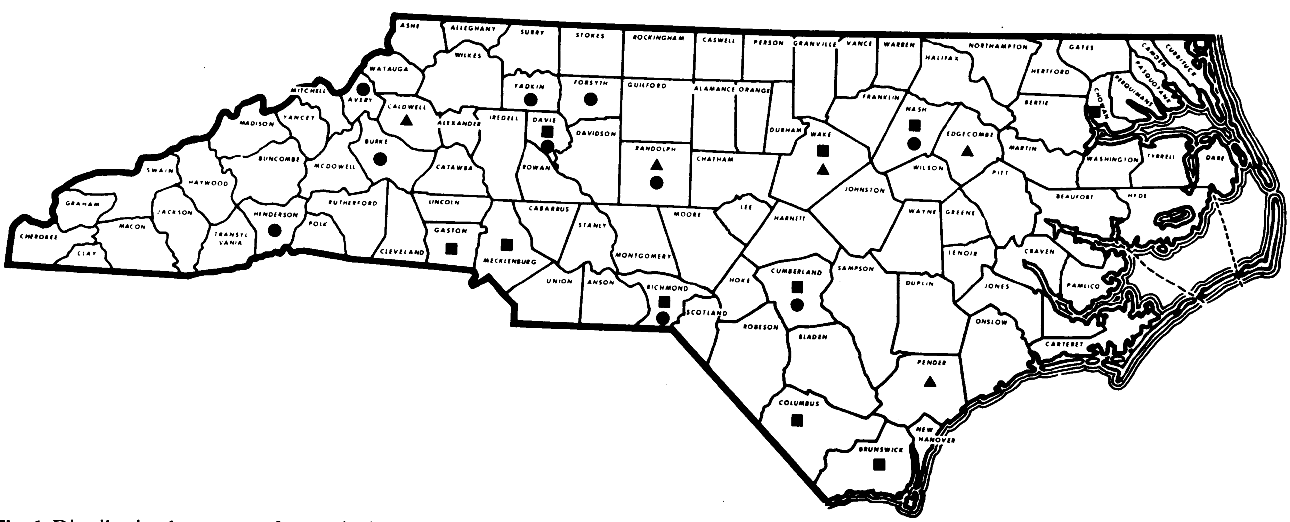

Fig. 1. Distribution by county of nurseries in North Carolina that were sampled in the disease loss assessment for Phytophthora root rot of azalea (■), nematodes on Japanese holly (▲), and Phytophthora dieback and root rot of hybrid rhododendron (●).

Table 5. Frequency of occurrence and nematode density of several plant-parasitic nematodes on field-grown Japanese holly at five randomly selected nurseries in North Carolina

Nursery	Total plants	Plants sampled	Plants with nematodes (%)				Nematode density (no./500 cm^3 of soil)[a]		
			Root-knot	Stunt	Ring	Lesion	Root-knot	Stunt	Ring
A	15,339	54	20	76	41	6	165 ± 524	180 ± 351	125 ± 349
B	5,431	55	5	36	9	9	4 ± 17	56 ± 158	16 ± 79
C	7,514	51	8	47	4	0	13 ± 45	31 ± 61	1 ± 5
D	4,868	34	12	38	12	3	10 ± 31	42 ± 71	24 ± 92
E	1,274	43	21	100	19	77	61 ± 313	518 ± 431	8 ± 28
Totals	34,426	237	13	59	17	19	51 ± 68	165 ± 202	35 ± 52

[a] Average number per plant sampled.

taken at each of the 10 nurseries. The species isolated were *P. cactorum*, *P. citricola*, *P. heveae*, and *P. nicotianae* var. *parasitica*. Isolates were recovered readily from infected stem and leaf tissue.

Japanese holly nurseries. Typical symptoms of nematode injury were seen only on plants at nurseries A and D. However, *Meloidogyne* sp. (root-knot), *Tylenchorhynchus* sp. (stunt), and *Macroposthonia* sp. (ring) were found on Japanese holly at all nurseries surveyed, whereas *Pratylenchus* sp. (lesion) was found in four or five nurseries.

Frequency of specific nematode occurrence varied by nursery as well as by nematode. In general, root-knot and ring nematode were found on 20% or less of the plants sampled, while stunt occurred on 35–100% of the plants sampled, depending on nursery (Table 5). Lesion nematode occurred on less than 10% of the plants sampled in nurseries from the coastal plain and piedmont areas of North Carolina, but lesion nematode was found on more than 75% of the plants at nursery E, located in the mountains. Density of root-knot and stunt nematodes was greatest at nurseries A and E, whereas ring was greatest at nursery A (Table 5). On a nursery basis, root-knot averaged 51 nematodes per 500 cm^3 per plant, stunt 165/500 cm^3 per plant, and ring 35/500 cm^3 per plant.

Time and cost estimates. A total of 4,086 km was traveled for the 25 nurseries surveyed during 110 man-hours. Azalea nurseries were surveyed in 62 man-hours. Two people could normally survey an azalea nursery in 2 hr. However, rain delays and time spent visiting with the nurseryman extended survey time. Laboratory time to make media, pour plates, wash and plate roots, and read the plates involved about 13 man-hours per nursery. A total of 245 man-hours at a cost of $3,240 or $3 per sample was spent for the survey of 10 azalea nurseries.

Rhododendron nurseries were surveyed in about 2–4 man-hours per nursery. Generally, the larger the nursery, the more time spent in surveying. A total of 94 man-hours at a cost of $1,959 or 2.7 per plant was spent for the 10 rhododendron nurseries surveyed.

Japanese holly nurseries took the most time to survey (33 man-hours) per nursery because 10 probes were needed per plant. Laboratory time was also greatest for Japanese holly nurseries because both roots and soil had to be assayed for nematodes. A total of 150 man-hours at a cost of $1,998 or $8.34 per sample was spent for the five Japanese holly nurseries.

DISCUSSION

Incidence of Phytophthora root rot of azalea was variable from nursery to nursery. Because of this, standard error was 80% of the estimate. Although the method used offered an unbiased estimate of disease incidence, variability greatly restricted the confidence that can be put in the estimate. However, the great variability among nurseries was expected because no two nursery operations were the same. For instance, potting mix components and ratios were not the same at any nursery. Irrigation, fertilization, and light conditions also were highly variable for the nurseries surveyed.

The azalea nursery survey confirmed that Phytophthora root rot was present in every nursery surveyed. In 6 of 10 nurseries, disease incidence was less than 8%; in 4 of 10 nurseries, incidence was 10–19%.

Because variability was great among nurseries as well as among plants surveyed, improvements in estimates of disease incidence will come only by sampling more nurseries and by taking more samples at each nursery. Any improvement in estimate of disease incidence will come, however, with a corresponding increase in survey costs.

The high incidence of root rot on cultivars in the Kurume hybrid group was expected because root-rot resistance in this hybrid group is low to moderate (3). Unfortunately, Kurume hybrids made up more than 50% of the azaleas grown in North Carolina.

As with azalea nurseries, variability of estimates among rhododendron nurseries was great. Part of the variation was caused by growing conditions among nurseries. In nurseries growing rhododendron in full sun, incidence of dieback was very low compared with incidence for nurseries growing in partial shade. In full sun, infection periods (4) are short because the foliage dries faster after irrigation or rain and plants are generally less succulent.

Frequency of occurrence of plant-parasitic nematodes known to cause decline in Japanese hollies (1,2) ranged from 4 to 100% of the plants sampled. The high incidence, particularly of *Tylenchorhynchus* sp., is of concern; however, it may reflect the status quo of field production of hollies, wherein the nematodes are fairly widely distributed and the chances of encounter with a perennial crop are intensified. Consumers knowingly or unknowingly accept a minimum of one in 10 plants infected with plant-parasitic nematodes.

The tremendous variability found in estimates of nematode density per plant demonstrates the need for collecting a greater number of samples per nursery. Because nematodes are not distributed at random in agricultural soils, the ability to make nematode density estimates of a greater precision may be cost-prohibitive on a survey basis.

In designing future surveys, decisions on the level of precision required will greatly affect the amount of time and money needed to conduct the survey. Unlike agronomic crops that are grown under more uniform management practices in a given geographic area, ornamentals, particularly in container-production, are subject to tremendous differences in management among nurseries. Sometimes the only two factors in common among nurseries are the plant cultivar and the plastic container holding it. The cost of greatly improving the estimates may be prohibitive.

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