Relationship of Soil Temperature and Moisture to Development of Phytophthora Root Rot of Azalea[1]

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Abstract

Temperature and moisture effects on development of Phytophthora root rot of azalea caused by *Phytophthora cinnamomi* was compared for plants growing in containers and a landscape bed in both sun and shade environment. Symptoms of Phytophthora root rot developed earlier and disease severity was greater on plants grown in the landscape bed where soil temperature and moisture in the root zone of infected plants favored disease development. Disease severity was similar for plants in the bed regardless of exposure to the sun or shade. In container culture, disease severity was greater on plants in the shade where medium temperature was lower and moisture was greater, than on similar plants exposed to the sun.

Index words: *Phytophthora cinnamomi, Rhododendron obtusum*, environmental stress

Introduction

Development of Phytophthora root rot in landscape and nursery crops is favored by soil moisture near saturation in the root zone which is critical in sporangium production, zoospore release, and subsequent infection of host root tips (2,3). Factors that improve drainage in the root zone such as changes in soil texture, organic amendments such as pine bark, and avoidance of excess irrigation, should lessen the incidence and severity of disease through a direct effect on matric potential. In many regions of the United States, nurserymen have adopted container production for crops partly to decrease the risk of root disease associated with in-ground production. In container culture, the nurseryman has more control over the growing environment including the use of pathogen-free media such as pine bark (6), hardwood bark compost (5) or other soil-less components. Although these practices are based in part on phytopathological research, actual comparison of environmental differences including media temperature and moisture for similar plants growing in containers and landscape beds has not been made.

The present study compares the development of Phytophthora root rot caused by *Phytophthora cinnamomi* and growth of azalea in containers and landscape beds as influenced by medium temperature and moisture.

Materials and Methods

Container plants. One-year-old azaleas (*Rhododendron obtusum* Planch. 'Hinodegiri') grown in steamed soil:sand:peat (1:1:1 by vol) at pH 5 in 2.6-liter (#1) plastic containers were transplanted May 26, 1983, to 5.7-liter (#2) containers of the same medium. Lime and superphosphate each at the rate of 3.8 kg/m^3 (6.4 lb/yd^3) were incorporated in the potting mix.

A mixture of four isolates of *P. cinnamomi* (mating type A[2]) from azalea and rhododendron were used as inoculum. The isolates were grown individually on autoclaved oat grains for 30 days prior to mixing of inoculum by hand from each culture. The azaleas were inoculated on June 10, 1983 by placing 30 colonized oat grains into each of three holes punched in the medium at the edge of the root ball. An equal number of plants not inoculated served as a control.

One-half of the plants were placed under 50% plastic shade cloth and the other half were placed in full sun on a container area in a research nursery at Raleigh, NC. Plants were arranged in a randomized complete block design with four replications and four observations per treatment each for shade and sun. Plants were fertilized with 15 cm^3 (6 in^3) of slow release 19N-2.6P-9.9 K (19-6-12), fertilizer per container at the beginning of each growing season. During the growing season plants were irrigated daily (0.9 cm/day or 0.3 in/day) by sprinklers and fertilized weekly with liquid 21N-3.0P-5.8K (21-7-7) fertilizer at a rate of 1.8 g/ml (16.8 oz/gal) applied with a water siphon proportionator. Plants in containers were overwintered under white copolymer plastic without supplemental heat.

Landscape beds. A (3.1 × 30.4 m or 10 × 100 ft) bed that had a past history of Phytophthora root rot was used at the research nursery. The soil was the B horizon of a poorly-drained, Cecil clay soil (pH 5.8). The A horizon was removed several years prior to establishing the nursery site. The bed was divided into eight sections, each 3.8 × 3.1 m (12 × 10 ft) and rototilled to 15 cm (6 in). Prior to planting, four sections were selected at random and fumigated with methyl bromide (0.68 kg/5.5 m^2 or 2.5 lb/100 ft^2) October 4, 1982. The other four sections were left unfumigated. Each fumigated and unfumigated section was planted 2 weeks later in a randomized complete block design with eight, 1-year-old Hinodegiri azaleas that were similar to the plants transplanted to the 5.7-liter (#2) containers. One-half of the fumigated and one-half of the unfumigated sections were covered with plastic shade cloth (50% light transmission) on wire frames and the other half were exposed to full sun.

The bed was top-dressed with a 3 cm (1.2 in) thick layer

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of pine bark mulch to conserve soil moisture and suppress weed development. At the beginning of each growing season the bed was top dressed with pre-emergence herbicide (Ronstar 26, 0.3 lb/100 ft^2) and with 11 kg 10N- 4.3P-8.3K (10-10-10)/100 m^2. In 1984 unusually wet conditions necessitated a second application of fertilizer on June 26. Post-emergence herbicides were used as needed for weed control during the growing season. Irrigation was used when needed to ensure at least 2.8 cm/wk (1 in/wk) of moisture during the growing season.

Environmental monitoring. A CR-21 micrologger (Campbell Sci., Logan, UT 84321) with thermistors was used to monitor air temperature in the plant canopy, medium temperature at a depth of 15 cm (6 in) in the container, and soil temperature at 10 cm (4 in) in the bed. Data was collected every 3 min then averaged over the hour so that 24 values were obtained for each 24 hr period. Data stored on tape was fed to a mainframe computer for analysis and plotting.

A mercury manometer system was constructed for use in observing matric potentials (i.e. amount of moisture) in container media and soil (1). Matric potential is measured in bars or millibars (mb). The wetter the soil the closer the matric potential reading to zero. The system consisted of a mercury reservoir attached to a 75 cm (30 in) high board and connected to a 10 cm (4 in) diameter ceramic tip in the plant root zone (10 cm or 4 in deep) via a 1.5 mm (0.06 in) inside diameter water-filled plastic tube. As moisture was removed from the root zone through transpiration, drainage, or evaporation, water was drawn out of the ceramic tip and mercury rose in the capillary tube. The height of the mercury column in the capillary tube above the mercury reservoir was read and expressed as millibars (mb) from a calibrated guide (Soil Moisture Equip. Co., Santa Barbara, CA 93105) attached to the board each work day at 0800 and 1630 hr during the growing season to monitor matric potential.

Disease assessment. Plants were observed for development of foliar symptoms of Phytophthora root rot during the 1983 and 1984 growing seasons. Root samples were collected with a 1.7 cm (0.07 in) diameter soil sampling tube from under the canopy of each plant. The samples were placed in plastic bags until the roots were washed free of the soil fraction in running tap water, blotted, and transferred in 1 cm (0.4 in) long clumps (5/plate), each containing 8 to 15 root pieces, to a modified pimaricin-penicillin-polymixin medium (4). Pimaricin concentration was reduced to 10 mg/L (10 ppm). A plant was considered infected if any of the 10 root clumps (2 plates/sample) yielded *P. cinnamomi*.

At the end of the second growing season (October 3, 1984) plant growth as measured by a rating scale where 1 = healthy roots, 2 = fine roots necrotic, 3 = coarse roots necrotic, 4 = crown rot, and 5 = dead plant were assessed.

Results and Discussion

Plant growth after 2 years was greater for azaleas in containers than in beds regardless of exposure (Fig. 1). Plant growth was similar for inoculated plants in containers in the sun and shade. However, uninoculated plants in containers in the sun were smaller than those in the shade. Plants grown in unfumigated sections of the bed were smaller than similar plants grown in fumigated sections (Fig. 1). However, in the bed no difference in growth of azalea was found for exposure.

The percentage of plants with symptoms of Phytophthora root rot ranged from 0 to 88% of the plants after the first year (Table 1). More plants with symptoms of Phytophthora root rot were observed in the bed than in containers (Table 1). Symptoms of Phytophthora root rot were observed in 100% of the plants in the unfumigated sections of the bed, and in 33 to 63% of the inoculated plants in the containers depending on exposure at the end of the second year. Uninoculated plants in containers and plants in fumigated sections of the bed developed symptoms of Phytophthora root rot by the end of the second year with the greater percentage of symptoms on plants in the fumigated sections of the bed. Recovery of *P. cinnamomi* from root samples of individual plants increased from 0 to 100% during the 2nd year (Table 1). The pathogen was recovered from about 50% of the plants 9 months after planting in the bed, but increased to 100% after 2 years. In the fumigated sections of the bed, *P. cinnamomi* was not recovered from plants grown in the shade until the second year, although recovery increased dramatically to 63% after 2 years. Recovery of the pathogen from plants grown in the sun ranged from 31% after 9 months to 56% after 2 years. *Phytophthora cinnamomi* was recovered from 100% of the inoculated plants, grown in containers in the shade but recovery was low for plants grown in the sun after 2 years. Recovery from uninoculated plants regardless of exposure was low.

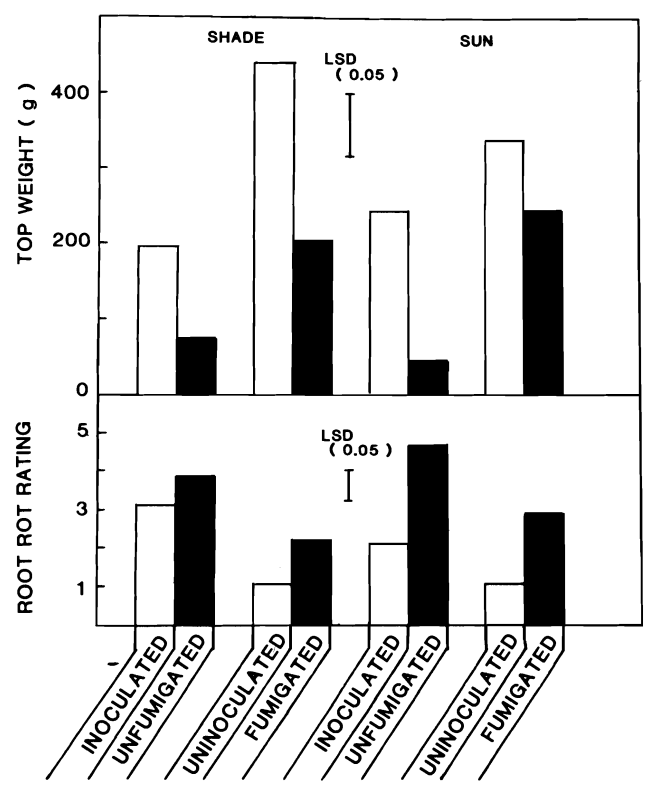

Fig. 1. Fresh top weight and root rot rating for Hinodegiri azalea grown for two seasons under either shade cloth or sun in either 5.7 L (#2) containers (open bars) or a landscape bed (solid bars) infested with *Phytophthora cinnamomi*.

Table 1. Percent symptom expression and recovery of *Phytophthora cinnamomi* from Hinodegiri azaleas over a 2 year period for plants in containers or landscape beds in the shade or in the sun.

Site/exposure	Symptoms (%)		Recovery of *P. cinnamomi* (%)			
	June 84	Sept 84	July 83	Oct 83	June 84	Sept 84
Container						
Shade						
Inoculated	19	63	0	56	69	100
Uninoculated	0	13	0	0	0	0
Sun						
Inoculated	27	33	0	0	0	6
Uninoculated	19	19	0	0	6	13
Landscape bed						
Shade						
Unfumigated	88	94	69	94	100	100
Fumigated	0	38	0	0	13	63
Sun						
Unfumigated	75	100	50	63	88	100
Fumigated	13	50	31	31	50	56

Phytophthora root rot was more severe on azaleas grown in the bed and exposed to the sun than on similar plants grown in containers (Fig. 1). No difference in root rot severity was found for plants exposed to the shade and grown in containers or beds respectively. Uninoculated plants grown in containers appeared to have healthy roots, after 2 years, however, plants grown in fumigated sections of the bed developed root necrosis with severity ratings of two to three (Fig. 1). Apparently, plot size and/or fumigation efficiency was not adequate to prevent infection in fumigated sections after 2 years.

Differences in temperature and moisture in the root zone of containerized and bed-grown plants may account for differences in severity of disease. Maximum temperatures in the root zone of plants grown in the bed and exposed to the shade ranged from 18–25°C (65 to 77°F) between June and August, 1984, while maximum medium temperatures for container plants exposed to the shade ranged from 19–33°C (67 to 92°F) (Fig. 2A). Similar differences in temperature between bed and container-grown plants exposed to the sun were observed. The lower temperatures in the root zone of plants grown in the bed regardless of exposure would favor development and colonization of *P. cinnamomi* which has a growth optimum near 26°C (79°F) (7). Due to the relatively small soil mass, temperatures in the root zone of container-grown plants fluctuated more during the day (up to 8°C (15°F) between max-min) than temperatures in the root zone of plants in the bed (up to 2.5°C (5°F) between max-min). In general, soil temperature in the bed was lower in the root zone of plants grown in shade than in sun (Fig. 2A).

Rainfall was abundant in June, July, and the first week of August 1984, followed by a severe drought during the next 30 days (Fig. 2B and 2C). Adequate moisture was provided for plants growing in containers and in the bed by daily and weekly irrigation, respectively.

Soil moisture, as measured by matric potential, had a significant effect on disease development (compare Fig. 1, 2D, and 2E). Data for matric potential reading at 1630 hr is presented since this time reflected the greatest moisture stress period during the day for plants in containers. At 0800 hr, matric potential for plants in containers ranged from 0 to −10 millibars (mb), since the irrigation system had just turned off. Little diurnal change was observed for matric potential in the root zone of plants in the bed.

Uninoculated plants in containers exposed to the sun were driest (−10 to −50 mb) at 1630 hr reflecting the effect of transpirational demands of the healthy plant with a large root system on available water in the container (Fig. 2D). matric potential for inoculated plants in the sun and inoculated and uninoculated plants in the shade ranged between 0 and −10 mb at 1630 hr, a matric potential favorable for zoospore release (2,3). Thus, even during the hottest and driest period of the day, soil moisture in containers was favorable for disease development.

Phytophthora root rot was more severe on plants in containers exposed to the sun than plants in the shade (Fig. 1). The effect of pathogen induced root dysfunction and lack of water extraction from the container was observed in late July as matric potential at 1630 hr increased dramatically for inoculated plants exposed to the sun compared to matric potential values for the other plants (Fig. 2D).

Severity of Phytophthora root rot was similar for plants grown in the bed and exposed to shade or sun (Fig. 1). Matric potential ranged from 0 to −10 mb at 1630 hr for inoculated plants and plants in fumigated sections of the bed in sun (Fig. 2E). On many days matric potential was near 0 mb at 1630 hr for inoculated plants in the beds reflecting the optimum environment for root rot development. Plants in fumigated sections of the bed and exposed to the shade extracted more water from the root zone and were at matric potentials (−10 to −50 mb) less favorable for root rot.

In this experiment, soil temperature and moisture were more favorable to development of Phytophthora root rot for plants grown in a landscape bed than for plants grown in containers. Soil temperatures fluctuated diurnally and reached values comparable to air temperatures in containers, while the more vigorously growing plants extracted more water out of the root zone and thus reduced the matric potentials favorable for root rot development. In the bed, daily soil temperature fluctuated little and was closer to the optimum for *P. cinnamomi*. Soil moisture in the root zone of infected plants in the bed was favorable for root rot development most of the summer since rainfall was frequent and infection of plants and subsequent root dysfunction prevented extraction of water from the root zone.

Significance to the Nursery Industry

Production of azaleas in ground beds should be discouraged in regions of the country where Phytophthora root rot is a problem, since disease incidence and severity were greater for plants in beds than for plants in containers. Differences in disease development between beds and containers were due primarily to temperature and moisture. In containers, temperature and moisture were less favorable to Phytophthora root rot during the day particularly on plants grown in the sun. Further research is needed to determine the exact relationship among container medium, irrigation frequency and Phytophthora root rot.

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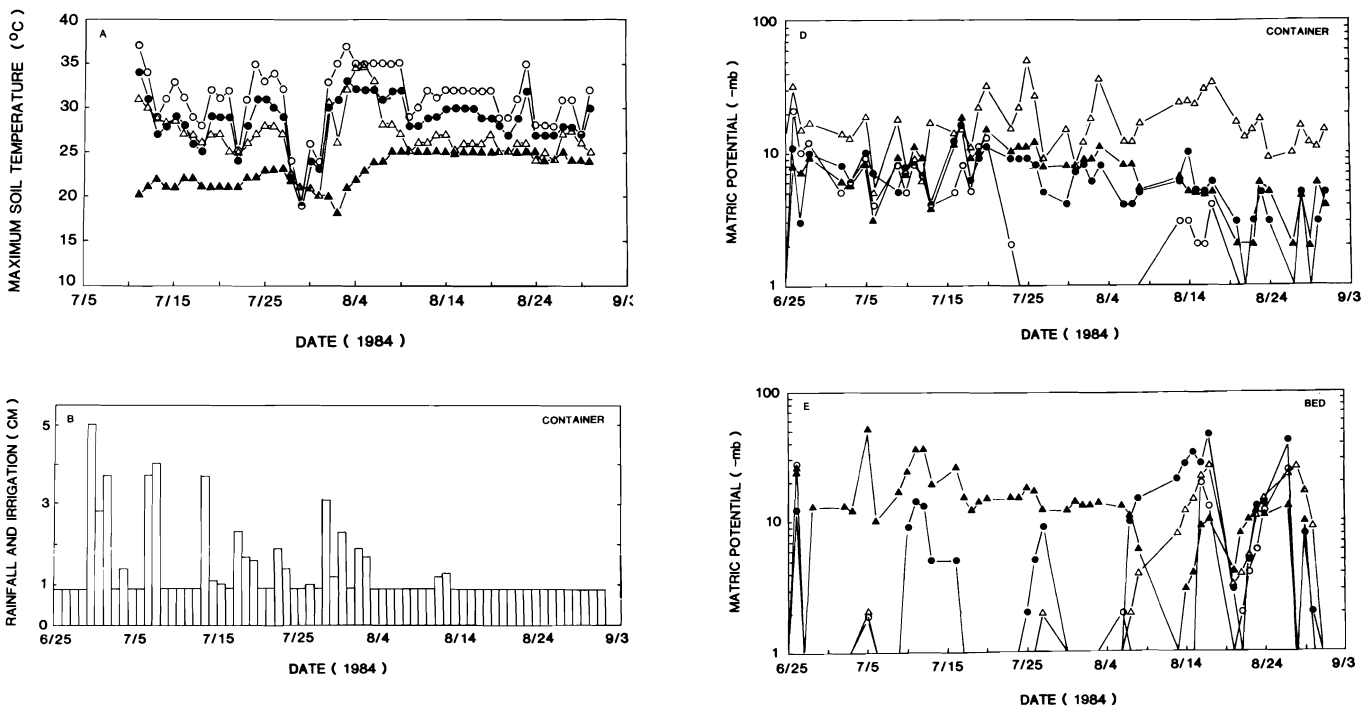

Fig. 2. Environmental data for Hinodegiri azaleas growing under shade or sun in 5.7 L (#2) containers or a landscape bed infested with *Phytophthora cinnamomi* during the second season. (A) Soil temperature in containers and in a landscape bed. Legend: container temperature-sun (○), container temperature-shade (●), soil temperature in bed-sun (△), and soil temperature in bed-shade (▲). (B) Rainfall and irrigation in containers. (C) Rainfall and irrigation in a landscape bed. (D) Soil matric potential in containers. Legend: inoculated-sun (○), uninoculated-sun (△), inoculated-shade (●), and uninoculated-shade (▲). (E) Soil matric potential in a landscape bed. Legend: unfumigated-sun (○), fumigated-sun (△), unfumigated-shade (●), fumigated-shade (▲).