In the nursery, the pot on the patio, or the large planting box at the mall, container plantings are susceptible to a myriad of pests. Because of these plants' exposure to the public, safe and effective pest management practices must be developed.

Nonchemical control methods—such as temperature management and the use of insect-parasitic nematodes or antagonistic fungi—are being studied and developed for specific ornamental plant situations. For nursery owners, potting soil quality can also be a critical issue in disease resistance. And when transplanting into a landscape, a gardener's irrigation techniques can help fend off disease.

Hibiscus rosa-sinensis "Kona" is severely affected by Phytophthora root and crown rot in California nurseries.

Environmental Factors Influencing Phytophthora Root Rot Severity in *Hibiscus Rosa-Sinensis*

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Phytophthora parasitica causes a root and crown rot disease in container-grown *Hibiscus rosa-sinensis* which is a widespread problem in California nurseries. Many hibiscus varieties are susceptible, but "Kona" and "White-wings" are the most severely affected.

The occurrence and severity of Phytophthora root and crown rot diseases can be strongly influenced by plant stress. While there has been progress on the subject of stress predisposition over the past decade, we still do not have enough information about specific stresses or predisposition thresholds to guide management decisions on many crops. The development of effective, nonchemical disease management practices requires knowledge of the environmental factors which most influence plant susceptibility.

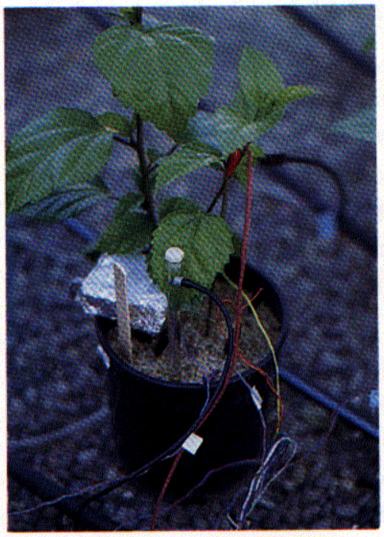
The purpose of this project was to study the individual and combined effects of irrigation frequency, root aeration and root temperature on Phytophthora root rot of container-grown hibiscus. Our experiments showed that heat stress of roots was the most significant factor affecting disease severity.

Hydroponic and Soil Container Experiments

Terminal stem cuttings of *Hibiscus rosa-sinensis* L. "Kona" were rooted by dipping their cut ends in 8,000 parts per million K-IBA (potassium salt of indole-3-butanoic acid) and suspending them in an Ein Gedi aerohydroponic unit. This method provided rooted cuttings known to be pathogen-free and with roots free of any rooting medium.

In one experimental approach, the rooted cuttings were grown hydroponically in two-liter ceramic crocks

Nursery bed showing young *Hibiscus rosa-sinensis* plants spaced to assure full exposure of containers to afternoon sun. In the background is the 72-percent shade cloth used to protect half of the plants from full sun exposure.



A young *Hibiscus rosa-sinensis* plant instrumented to monitor the temperature, water tension and oxygen diffusion rate in the root zone. Several such plants were used in the sun-exposed and shaded areas of the nursery bed to monitor the root environment during experiments.

containing half-strength Hoagland's solution. Plants were grown nine days with periodic solution changes to assure freshness. After the initial growth period, roots were exposed to temperatures ranging from 20° to 50°C by immersion in temperature-controlled water baths. Each bath contained several glass beakers filled with half-strength Hoagland's solution, and roots of individual plants were dipped in separate beakers. A total of twelve plants were exposed to each temperature for a period of 20 minutes. Following removal from the water baths, half the plants from each temperature treatment were inoculated by immersing their roots in solutions containing zoospores of *Phytophthora parasitica* Dastur. After a four-hour exposure to the inoculum, they were transferred back to the crocks of half-strength Hoagland's solution and observed over a 10-14 day period for symptom development. Disease severity was assessed by visually estimating the percent of roots infected and by determining the percent of root pieces from which *P. parasitica* was recovered when cultured on selective agar media. These experiments were repeated a total of four times.

In other experiments, rooted cuttings were potted into 5-inch black plastic containers filled with a one-to-one (by volume) peat-sand potting mix. Those hibiscus plants were potted singly in the containers, approximately one inch from the container wall. This off-center planting maximized root contact with the inner wall of the container in a relatively short growing period. The plants were grown for fifteen days in a greenhouse without supplemental lighting with day/night temperatures of 21° and 15.5°C respectively. They were watered daily with half-strength Hoagland's solution.

After the fifteen-day growth period, the hibiscus containers were moved to an outdoor gravel nursery bed for an eight-hour (10:00 A.M. to 6:00 P.M.) period and the pots were arranged so that the planted sides faced west to assure maximum exposure to the afternoon sun. One half of the plants were in the open where they were fully exposed, while the other half were protected under 72-percent shade cloth. At the time the plants were arranged in the bed, electronic temperature sensors were inserted into the root zones of several in the exposed and shaded groups. Soil temperatures were measured and recorded every 30 minutes with a programmable data logger. After the plants were moved back into the greenhouse, half of those in the sun-exposed treatment and half from the shaded treatment were inoculated with zoospores of *Phytophthora parasitica*. They were all observed over the next eight to ten days, after which they were harvested.

The extent of root infection was visually estimated by removing a root sample from each plant, washing away the potting mix, and estimating the percent of infected (necrotic) root tissue. We also quantified infection by means of a *Phytophthora*-specific immunochemical test (an enzyme-linked immunosorbant assay, or ELISA). The ELISA tests can be used to compare infection severity because the intensity of a test reaction is closely related to the amount of *Phytophthora* present in a tissue sample. The intensity of the test reactions were measured with a spectrophotometer, and this experiment was performed twice during the summer months.

Effects on Roots Exposed to Various Temperatures

In the hydroponic experiments, infection severity increased as the temperature to which roots were exposed increased. Necrotic lesions developed all along the inoculated roots, but the extent of the necrosis differed among the various temperature treatments. At the highest temperature (50°C) there was considerable heat injury of roots, as evidenced by the 80-percent necrosis of noninoculated roots. But inoculated roots heated to the same temperature were 100-percent necrotic, and the fungus had grown rapidly upward to infect the lower stem tissue.

When roots were exposed to temperatures of 40°C, there was very little subsequent injury to those that were not also inoculated. Roots that were inoculated after heating to 40°C developed extensive (approximately 75-percent) necrosis, and the pathogen rapidly advanced upward into the lower plant stem. Roots exposed to 30° or 22°C before inoculation developed only 35-percent and 20-percent necrosis respectively, and there was no sign of pathogen advance into lower stem tissues. In the absence of inoculation, roots exposed to 30° or 22°C treatments were completely unaffected. Recovery of *P. parasitica* from root pieces cultured on agar media gave results that closely corresponded with visual ratings; the percent of root segments from which the pathogen was recovered increased with increasing root exposure temperature.

In the first of the two nursery bed experiments, root zone temperatures in the hibiscus which were fully exposed to the afternoon sun increased from 27°C in the morning to 48.5°C in the late afternoon. Temperatures in the root zones of shaded plants were comparatively much lower, reaching a maximum of only 34.5°C. In the two weeks following inoculation and transfer back to the greenhouse, no above-ground disease symptoms, such as leaf yellowing or wilt, developed on inoculated plants from either the sun or shade treatments. When root samples were collected for examination, lesions were evident but difficult to quantify on the washed samples.

Roots of *Hibiscus rosa-sinensis* 'Kona' grown in hydroponic culture and exposed to various temperatures before inoculation with *Phytophthora parasitica* zoospores. Exposure temperatures were (left to right) 20°, 30°, 40° and 50°C for 20 minutes. Plants across the top were not inoculated, while those across the bottom were inoculated following heat exposure.

However, the antibody tests revealed large differences in the extent of fungal colonization of the roots. There were very high levels of *P. parasitica* detected in the roots of sun-exposed, inoculated plants, while there were barely detectable levels in the roots of plants maintained in the shade.

In a second nursery bed experiment, root zone temperatures in sun-exposed containers reached a maximum of 52°C, while shaded roots were 12 degrees cooler. This time, severe wilt and lower stem infections developed on inoculated, sun-exposed plants within five days of their return to the greenhouse. No disease symptoms ever developed on the inoculated plants from the shade treatment. Again, visual estimates of infection severity were difficult to obtain in the washed samples, but the ELISA tests revealed significant treatment effects. Root samples from sun-exposed, inoculated plants had very high levels of *P. parasitica* present, while the shaded, inoculated plants had barely detectable levels.

Moderating Heat Stress

These experiments showed that temperature stress predisposes hibiscus roots to infection by *P. parasitica*, a significant conclusion considering that temperatures occurring above 40°C are common in the root zones of container-grown plants. In fact, during the summer months, if container walls are exposed to the late afternoon sun, root zone temperatures can exceed 55°C.

In the hydroponic experiments, immersing roots in solutions heated to 40°C for twenty minutes was enough to predispose them to severe infection. Exposure to lower temperatures had correspondingly smaller effects on disease. In the experiments where plants were placed outdoors and exposed to a single cycle of solar heating, roots were exposed to high temperatures for much longer times than those in the water bath experiments. But even though exposure times were longer and temperatures exceeded 50°C, there was no sign of direct heat injury to any uninoculated roots as was seen in the hydroponic experiments. Apparently the potting mix or the more gradual increase in temperature afforded some protection against direct injury. This may also explain why shaded roots in the second experiment were not predisposed to disease, even though they reached a temperature of 42°C. Hydroponically-grown roots exposed to the same temperature for only 20 minutes were predisposed and developed severe disease symptoms. Predisposition of roots grown in potting mix appeared to require temperatures of approximately 50°C.

Heat stress could influence disease through a variety of methods. One may be temporary changes in root cell membranes that increase leakage of sugars and amino acids, causing greater numbers of *Phytophthora* zoospores to be attracted to the roots. Also, physiological processes involved in host defense responses may be affected, allowing the fungus to more easily colonize and grow through root tissues.

There are a number of ways in which root zone temperatures can be moderated by nursery managers, but each introduces other factors which need to be considered. For example, white containers reflect some solar radiation but turn brittle with prolonged exposure to ultraviolet light. Our experiments showed that shading can keep root temperatures below predisposing levels, but this may not always be a practical or economical approach. Timing irrigations so that cooling water is applied before root temperatures peak also could help, but care must be taken to assure that shading of containers or changes in irrigation practice do not lead to an excessively wet and oxygen-deficient root environment. Such conditions have been shown to predispose other plants to infection by *Phytophthora* species and illustrate the complex nature of the environmental interactions within a container.

The knowledge that high root zone temperatures can increase the severity of Phytophthora root rot in hibiscus points out the importance of preventing excessive heating in this crop.

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