

Phytophthora Species in Arizona: Its Occurrence in Recycled Irrigation Water

Sherman V. Thomson and Ross M. Allen

Citrus leaf baits and sieves of monofilament cloth were used to collect *Phytophthora parasitica*, *P. citrophthora*, and *Phytophthora* spp. of uncertain identity from waste irrigation water being gathered in sumps for recycling to citrus orchards near Phoenix, Arizona. Occurrence of the *Phytophthora* species was seasonal and dependent on ambient water temperatures. Incidence of species pathogenic to citrus was sufficient to be considered a distinct hazard.

Introduction

Phytophthora foot rot causes substantial losses in more than 10,000 acres of irrigated citrus in Arizona. Collection and recycling of irrigation water is increasing in areas where water availability is limited. In some irrigation systems in Arizona, waste water (tailwater) is collected in large ponds or sumps and subsequently recycled to the cropped land from which it was collected. This practice, common with citrus growers, could result in increased incidence of foot rot caused by *Phytophthora* spp. Therefore, we investigated the possible presence of *Phytophthora* spp. in sumps and in water subsequently distributed to citrus trees by irrigation procedures (7,8).

Materials and Methods

Water from 20 sites in citrus areas near Phoenix was sampled periodically from November, 1970 through November, 1971. Representative sites were selected to enable sampling of water from the tailends of four irrigation ditches, nine sumps, recycled water at the head-ends of four irrigation ditches, and project water at two canal locations. Water from five sumps collecting waste water from crops other than citrus also was sampled. Methods of processing the samples have been described elsewhere (7,8).

A modification of a leaf bait technique (5) was used to trap zoospores

of *Phytophthora* spp. from irrigation water. Whole leaves of Rough lemon (*Citrus jambhiri*) were "feathered" by removing 2 mm strips from the leaf margins and making several short cuts, about 10 mm apart, perpendicular to the midrib. A string was tied to the petioles of three "feathered" leaves so that individual leaves were approximately 15 cm apart. These three-leaf-sets then were floated on irrigation water at field sites for at least 5 hr. Moist leaves were then transported to the laboratory for further processing and culture. Identification of *Phytophthora* isolates infecting test leaves were determined from keys and descriptions (1,2,4,6,10). Pathogenicity of these isolates was tested by inoculating stems and roots of Rough lemon seedlings and sweet orange fruits.

Results

Phytophthora spp. were isolated 93 times in 599 attempts from water at 20 different sites. With one exception, all *Phytophthora* spp. were isolated from waste water from citrus orchards. *Phytophthora parasitica* Dast. was isolated 26 times in water at 9 of the 20 collection sites and *P. citrophthora* (R. E. Sm. & E. H. Sm.) Leonian was isolated 25 times in water at 6 of the 20 sites. Both *P. parasitica* and *P. citrophthora* were isolated from waste water from citrus and recycled water being used to irrigate citrus, but not from water from non-citrus areas.

Many *Phytophthora* isolates could not be identified with certainty but were found to fit into three distinct morphological groups designated *Phytophthora* sp., Form A, B or C. These isolates had characteristics similar to *P. dreschleri* Tucker, *P. cryptogea*

Pethybridge & Lafferty and *P. lateralis* Tucker & Milbrath, respectively, according to Waterhouse (10).

Phytophthora sp., Form A, was isolated 10 times and only during the cooler months of February and March. *Phytophthora* sp., Form B, was isolated only once and Form C was isolated 31 times, more than any other *Phytophthora* sp. Form C was isolated from excess drainage and sumps from citrus groves but was also found one time in drainage water from cotton acreage.

Seventy-five percent of the isolations of *Phytophthora* spp. were made with the leaf baiting technique. *Phytophthora* sp., Form B was the only isolate not trapped with citrus leaf pieces. Citrus leaves and blossoms which had fallen into the irrigation water also were often infected with *Phytophthora* spp. The sieving technique was successful in isolating *P. parasitica*, *P. citrophthora*, and *Phytophthora* spp., Forms A and C, from irrigation water. Only *Phytophthora* sp., Form B was isolated (and only once) when using a dilution plate method with P₁₀VP selective medium (9).

Phytophthora parasitica was isolated when water temperatures were between 20 and 30°C, while *P. citrophthora* was found only when temperatures were below 23°C. *Phytophthora* sp., Form C was isolated most frequently when water temperatures were between 26 and 32°C.

Isolates of *P. parasitica* and *P. citrophthora* caused typical gummosis or brown rot symptoms on citrus stems, roots and fruit. Although *Phytophthora* isolates Forms A, B, and C occasionally produced a slow rot of the mesocarp and columella of the fruit,

About the authors — Sherman V. Thomson, Department of Plant Pathology, University of California at Berkeley, is a former UA Research Assistant. Ross M. Allen is a Professor in the Department of Plant Pathology, University of Arizona at Tucson.

the exocarp of the peel was not noticeably affected. Re-isolations could be made from the exocarp at the end opposite the inoculation in all fruits inoculated with *P. parasitica* and *P. citrophthora* but only from the columella or mesocarp in fruits inoculated with Forms A, B and C. Forms B and C were pathogenic to roots of Rough lemon seedlings but Forms A, B, and C caused no gummosis symptoms on stems of year-old Rough lemon seedlings.

Well-water initially was relatively free from fungi. However, after passage through a citrus orchard, or other cropped acreage, the water was heavily contaminated with many species and propagules of fungi (7,8). Salt River Project water was variable in the amount of contamination depending on the amount of tailwater and drainage that was added to the river water in the canal system.

Discussion

This study has established that some irrigation tailwater is contaminated with plant pathogenic *Phytophthora* species and that these fungi are present in water recycled from sumps to irrigate citrus. Those sumps tested which collected tailwater from citrus groves were all found to be infested with *Phytophthora* species capable of causing foot rot. *Phytophthora parasitica* was the predominant species isolated when water temperatures were over 20°C and *P. citrophthora* was not isolated when water temperatures were over 23°C. These findings suggest that both species may be present in citrus orchards or irrigation systems year-round, but that zoospore production is dependent upon environmental temperature.

All propagules of *Phytophthora* spp. found in irrigation water by the sieving technique were zoospores. Whiteside (11) demonstrated that infection of trunks of citrus trees by zoospores



Figure 1. Washington navel trees on Rough lemon rootstock show varying degrees of infection by *PHYTOPHTHORA PARASITICA*. Tree at right is nearly dead. Spaces exist where trees killed by fungus were removed. Tailwater (foreground) is collected in a sump for reuse in the same grove.



Figure 2. Eureka lemon on Rough lemon rootstock in advanced stage of infection. Symptoms include longitudinal cracking, peeling of bark; copious gumming and brown color of cambium layer; severe defoliation. Irrigation was flood type with recycled sump water.

of *Phytophthora parasitica* apparently occurred only when there were recent breaks in the bark. Since injuries to trunk and roots easily occur during cultivation procedures, subsequent early irrigation with water contaminated with *Phytophthora* spp. could easily provide the inoculum necessary for infection.

The significance of the *Phytophthora* spp., Form A, B, and C in irrigation water is uncertain. These species may be parasitizing natural weed-hosts or cultivated crops other than citrus. However, since Forms B and C were pathogenic to roots of Rough lemon they may be responsible for citrus root infections despite their in-

ability to cause bark gummosis on trunks.

The presence of *Phytophthora* spp. in recycled water is considered a serious threat for several reasons: first, many of the irrigation recycling systems provide contaminated water for susceptible citrus; secondly, *Phytophthora* spp. are particularly adapted to an aquatic environment; thirdly, flood irrigation systems wet trunks of trees and also place water in contact with roots; fourthly, all 70 described species of *Phytophthora* are pathogens of higher plants (3); and, fifthly, the dispersal of propagules in waste irrigation water could function as primary inoculum for noninfested orchards.

Literature Cited

1. BARNETT, H. L. 1960. *Illustrated Genera of the Fungi Imperfecti*. Burgess Publishing Co., Minneapolis, Minn. 225 pp.
2. BARRON, G. L. 1968. *The Genera of Hyphomycetes from Soil*. The Williams and Wilkins Co., Baltimore, Md. 364 pp.
3. ERWIN, D. C., G. A. ZENTMYER, J. GALINDO, and J. S. NIEDERHAUSER. 1963. Variation in the genus *Phytophthora*. *Annu. Rev. Phytopath.* 1: 375-396.
4. GILMAN, J. C. 1957. *A Manual of Soil Fungi* (2nd ed.) Iowa State Univ. Press, Ames. 450 pp.
5. GRIMM, G. R., and A. F. ALEXANDER. 1973. Citrus leaf pieces as traps for *Phytophthora parasitica* from soil slurries. *Phytopathology* 63: 540-541.
6. SPARROW, F. K., Jr. 1960. *Aquatic Phycomycetes*. (2nd ed.) Univ. Mich. Press, Ann Arbor. 1187 pp.
7. THOMSON, S. V. 1972. Occurrence and biology of *Phytophthora parasitica* and other plant pathogenic fungi in irrigation water. Ph.D. Diss., Univ. Arizona, Tucson. 120 pp.
8. THOMSON, S. V., and R. M. ALLEN. 1974. Occurrence of *Phytophthora* species and other potential plant pathogens in recycled irrigation water. *Plant Dis. Repr.* 58:945-949.
9. TSAO, P. H., and G. OCANA. 1969. Selective isolation of species of *Phytophthora* from natural soils on an improved antibiotic medium. *Nature* 223:636-638.
10. WATERHOUSE, G. M. 1963. Key to the species of *Phytophthora* DeBary. *Common. Mycol. Inst. Mycol. Papers* No. 92. 22 pp.
11. WHITESIDE, J. O. 1971. Some factors affecting the occurrence and development of foot rot on citrus trees. *Phytopathology* 61:1233-1238.