Root Diseases of Vegetables in Hydroponic Culture Systems in North Carolina Greenhouses

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ABSTRACT

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Pythium aphanidermatum, P. myriotylum, P. debaryanum, and *P. ultimum* were isolated from roots of diseased tomato, cucumber, and lettuce growing in greenhouse hydroponic systems. *Colletotrichum coccodes* was isolated from roots of diseased tomato, and *Pseudomonas solanacearum, Fusarium oxysporum* f. sp. *radicis-lycopersici*, and *Erwinia* spp. were isolated from stems near the base of diseased tomato plants. *F. oxysporum* f. sp. *cucumerinum* was isolated from stems of infected cucumber plants. All isolates were pathogenic on the host from which they were isolated. The four *Pythium* species, *C. coccodes, Pseudomonas solanacearum*, and *F. oxysporum* f. sp. *cucumerinum* were readily transmitted in the nutrient solutions of hydroponic systems. *Erwinia* spp. and *F. oxysporum* f. sp. *radicis-lycopersici* were not transmitted in the hydroponic system.

Additional key words: nutrient film technique

Many systems of soil and soilless culture are used to grow vegetables, including hydroponics. Two types of hydroponic systems, trough culture and nutrient film technique (NFT), recirculate the nutrient solutions over the root systems of the growing plants (14).

Several root-infecting pathogens have been reported on vegetables in hydroponic systems (3,4,8,9,11,12). *Pythium aphanidermatum* caused a 100% loss of tomato seedlings in Arizona (12) and *P. irregulare, Phytophthora parasitica* (2,9), *Sporangospora subterranea* (4), *Colletotrichum coccodes* (3,8,11), and *Verticillium* spp. (4) have caused significant losses.

At least 20 hydroponic systems have been installed by greenhouse vegetable growers in North Carolina during the past 10 yr. Tomato, cucumber, and lettuce are the principal crops grown in these systems. Root or stem disease problems have been numerous and severe, causing several business failures. Disease samples were submitted to the North Carolina State University Plant Disease and Insect Clinic or to one of the authors for diagnosis. This report lists the root or stem disease diagnosed, identification of the pathogens, and results of transmission tests of the organisms in trough culture and NFT systems.

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MATERIALS AND METHODS

Diagnosis and isolations. Specimens of greenhouse vegetables with symptoms of such root diseases as root rots or vascular wilts were examined microscopically for causal agents and isolations were made after identification. Tissues from the plant suspected of infection by *Pythium* spp. were rinsed in distilled water and plated on cornmeal agar for further studies. Stem tissue from tomato with symptoms of bacterial wilt caused by *Pseudomonas solanacearum* was soaked in 0.5% sodium hypochlorite for 5 min, rinsed in sterile distilled water, placed in sterile water blanks for 30 min, shaken, and a loop of the suspension streaked on tetrazolium medium (6). Tissues from other specimens were isolated on acidified potato-dextrose agar (PDA) or plain water agar (13).

Hydroponic systems. Simulated hydroponic systems used to test transmission of the pathogens were designed as follows: the NFT system (Fig. 1A) consisted of a black polyethylene tube painted white (1.2 m × 25 cm) with six holes cut (5 cm diam.) as openings to insert plants. Two trickle tubes (0.2 cm i.d.) connected an aquarium pump (Model 1-AA, Little Giant Pump Co., Oklahoma City, OK

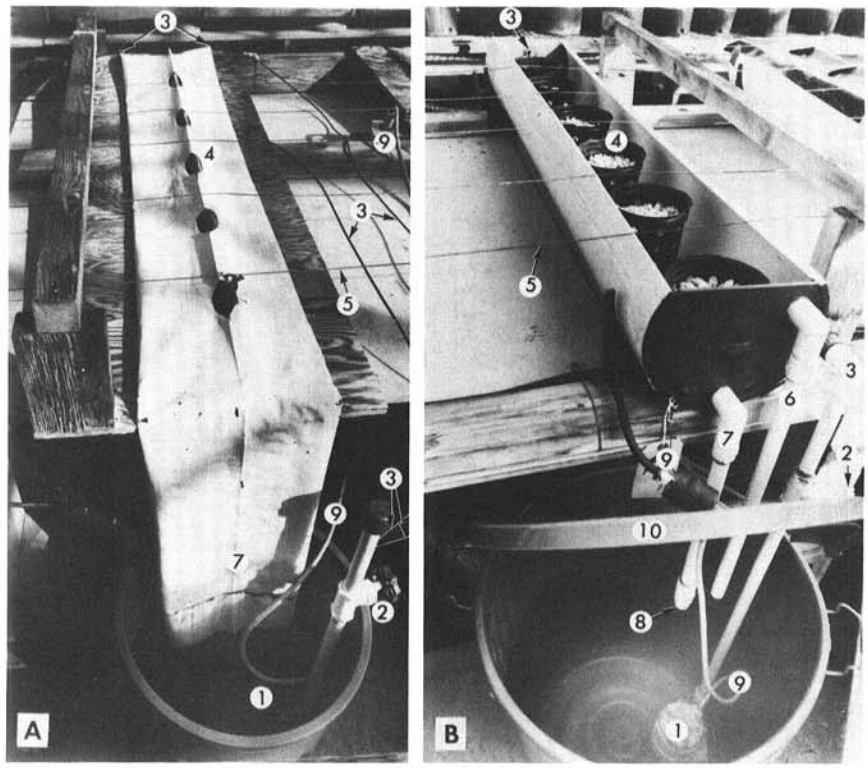

Fig. 1. (A) Nutrient film hydroponic system with (1) pump, (2) shutoff valve, (3) trickle tube, (4) black polyethylene tubing painted white, (5) plant support wire, and (9) electrical power line. **(B)** Trough hydroponic system with (1) pump, (2) shutoff valve, (3) PVC inlet pipe, (4) pot (12 × 12 cm) with gravel, (5) plant support wire, (6) overflow drain pipe, (7) outlet pipe, (8) outlet drain, (9) electrical power line, and (10) container cover.

73112) submerged in a 37.5-L covered container to the nutrient film. The end of the polyethylene tube was placed in the nutrient container. The nutrient solution (Hoagland) (5) returned to the reservoir in the tube by gravity on a 1:20 slope. The flow cycle of nutrients was regulated by a 10-min clock that was on 2 min and off 8 min.

The trough system (Fig. 1B) was constructed with 20-cm white polyvinylchloride (PVC) pipe with one-third of the side removed. Ends (15 cm high) were capped by gluing flat PVC cut to conform to the pipe. The resulting trough was 1.2 m long × 14 cm deep. The roots of six plants were supported in each of six polyethylene pots 12 × 12 cm containing washed gravel. Nutrients were pumped into the trough with a 1.6-cm inlet pipe and drained with a 1.2-cm outlet pipe at the bottom of the trough. An overflow 1.5-cm pipe was installed 2.5 cm from the top to drain excess nutrient solution. Both outlet pipes returned nutrients to the reservoir container. The inlet pipe was connected to a submersible aquarium pump contained in a covered 75-L reservoir. The nutrient flow was regulated by a 60-min interval timer for cycles of 7 min on and 13 min off.

Pathogenicity. Organisms isolated from diseased tomato, cucumber, or lettuce plants were grown on appropriate media and placed in the miniature (six-plant capacity) recirculating hydroponic systems containing Hoagland's nutrient solution (5) and evaluated for pathogenicity. *Pythium* spp. were grown on oatmeal agar for 7 days. The mycelial mat (one mat for each 37.5-L nutrient solution) was ground for 15 sec with 100 ml H_2O in a Waring Blendor. Inoculum of *C. coccodes* was prepared by washing conidia from the surface of actively growing colonies and preparing a suspension in the nutrient solution of 10^4 conidia per milliliter. The *Fusarium* spp. were grown on acidified PDA, ground 15 sec with 100 ml H_2O in a Waring Blendor, and added to the nutrient system at the rate of one mat in 37.5 L. *P. solanacearum* was grown in a liquid medium for 3 days, filtered on a Millipore filter (0.45 μm), and resuspended in water (6). *Erwinia* spp. were grown on nutrient agar and the bacteria were washed from the agar surface and added to the nutrient solution at the rate of 4.6×10^5 colony forming units per milliliter. Inoculum of each organism was added separately to the reservoir of the respective hydroponic system when plants were well established (4–6 wk old).

Plant-to-plant transmission. Pathogenic isolates of the various organisms isolated from one of the hosts (tomato, cucumber, or lettuce) were used for plant-to-plant transmission studies in the simulated hydroponic systems. Inoculum was prepared as in the pathogenicity studies and placed in contact with roots of a single plant growing in sand culture. After 4 days, the sand and excess inoculum were washed from the roots and the symptomless inoculated plant was placed into one of the six spaces in the trough. Five healthy plants were placed in the other spaces. The plants were observed daily for disease symptom development.

RESULTS

Isolates of fungi and bacteria obtained from infected tomato, cucumber, and lettuce plants included *Pythium* spp. on tomato, cucumber, and lettuce, *Colletotrichum coccodes, Fusarium oxysporum* f. sp. *radicis-lycopersici, Pseudomonas solanacearum*, and *Erwinia* spp. on tomato, and *F. oxysporum* f. sp. *cucumerinum* on cucumber (Table 1). About 50% of the *Pythium* isolates were identified to species and *P. aphanidermatum* was the predominant species. *P. myriotylum, P. ultimum*, and *P. debaryanum* also were recovered. The single *P. ultimum* isolate was recovered from cucumber plants where the temperature of the solution had been lowered to avoid a previous problem with *P. aphanidermatum*.

All pathogens listed in Table 2 were pathogenic on their respective hosts when inoculum was added to the nutrient solution in the reservoir, with the exception of *Erwinia* spp., *F. oxysporum* f. sp. *radicis-lycopersici*, and *F. oxysporum* f. sp. *cucumerinum*. The bacterium had been isolated from tomato plants with symptoms of bacterial hollow stem. When tomato plants were stem-inoculated with a needle wound at the third leaf axil, the plants showed symptoms of hollow stem. Isolates of *Pythium* spp. varied in the time required for disease symptoms to appear, but all plants eventually developed root necrosis. Tomato plants inoculated with *C. coccodes* developed symptoms; the lower leaves turned chlorotic and the plants died about 5–6 wk after inoculation.

Inoculum of pathogens from previously inoculated plants was transferred in the hydroponic systems to healthy plants, with the exception of *F. oxysporum* f. sp. *cucumerinum, F. oxysporum* f. sp. *radicis-lycopersici*, and *Erwinia* spp. *Pythium* spp. and *P. solanacearum* were easily transmitted in the nutrient solutions of the hydroponic systems, with the five uninoculated plants showing symptoms within 1 wk after the inoculated plant was placed in the system. The pathogen that showed symptoms most slowly after placing an inoculated plant in the system was *C. coccodes*, which usually required 12 days.

DISCUSSION

Recirculating hydroponic systems should remain free of root-infecting plant pathogens if proper sanitation procedures are followed. As indicated by this report, however, many systems have become contaminated with root-infecting pathogens. The most prevalent of these in North Carolina has been *Pythium* spp. Damage caused by this organism has ranged from very severe (100% loss) to light to moderate root or stem damage. This may have been due to variations in pathogenicity of isolates or to such factors as salt injury, caused by excess nutrients, which predisposes roots to

Table 1. Occurrence of root-infecting pathogens on cucumber, lettuce, and tomato in commercial hydroponic greenhouses in North Carolina, 1979–1981

Pathogen	Crop	No. observed
Pythium spp.	Cucumber	11
	Tomato	41
	Lettuce	1
Erwinia spp.	Tomato	2
Colletotrichum coccodes	Tomato	2
Pseudomonas solanacearum	Tomato	4
Fusarium oxysporum f. sp. *radicis-lycopersici*	Tomato	2
F. oxysporum f. sp. *cucumerinum*	Cucumber	3

Table 2. Number of days required for initial symptom appearance and 100% disease after introducing the pathogen into a hydroponic system

Pathogen	Host	Days	
		Symptom expression	100% disease
Pythium aphanidermatum	Cucumber, tomato	6	9
P. debaryanum	Cucumber, tomato	6	14
P. myriotylum	Cucumber, tomato	7	18
P. ultimum	Cucumber, tomato	10	22
Colletotrichum coccodes	Tomato	12	36
Pseudomonas solanacearum	Tomato	7	10
Erwinia spp.	Tomato	NT[a]	···
Fusarium oxysporum f. sp. *cucumerinum*	Cucumber	NT	···
F. oxysporum f. sp. *radicis-lycopersici*	Tomato	NT	···

[a] NT = Not transmitted.

more damage by otherwise weak pathogens (2). In contrast with soil culture, where older cucumber and tomato plants are not as susceptible to damage by *Pythium*, damage can be quite severe on older plants in a hydroponic system. The entire root system is exposed to the inoculum of the pathogen and severe root rot and subsequent plant death can occur in just a few days (Table 2).

We have not often observed bacterial wilt of tomato caused by *P. solanacearum* in commercial grower systems (Table 1), but in each case and in all inoculation studies on susceptible tomato cultivars, the bacterium was devastating, with 100% loss. We also have reports and specimens from growers in Alabama, Oklahoma, and New Zealand, where bacterial wilt caused serious losses. Root-to-root spread of *P. solanacearum* has been reported (7).

Infection of vegetables in hydroponic systems limits the usefulness of this production system unless suitable preventatives or controls are implemented. Sanitation practices to prevent introduction of pathogens into the system is the best control measure. Resistance to the pathogens tested is not available in varieties suitable for commercial vegetable production in North Carolina. There are very few chemicals currently registered for control of these diseases on greenhouse vegetables.

An advantage listed by advocates of hydroponics is the avoidance of soilborne diseases (1). Resh (10) listed the advantages of soilless culture as no diseases, insects, or animals in the medium and no need for crop rotation. Wittiwer and Honma (14) also listed the advantage of NFT in the elimination of soilborne diseases. Experience in North Carolina indicates, however, that root rots and wilts are serious problems in hydroponic systems. Hydroponic systems offer opportunities for developing new biological and chemical control measures because the biocontrol agent or chemical can be added to the circulating medium at one point for distribution throughout the system.

LITERATURE CITED

1. Carpenter, T. 1979. Will "home-made" hydroponics work? Am. Veg. Grower 27(11):16-18,68.
2. Csinos, A., and Hendrix, J. W. 1978. Parasitic and nonparasitic pathogenesis of tomato plants by *Pythium myriotylum*. Can. J. Bot. 56:2334-2339.
3. Daughtrey, M. L., and Schippero, P. A. 1980. Root death and associated problems. Acta Hortic. 98:283-291.
4. Davies, J. M. L. 1980. Disease in NFT. Acta Hortic. 98:299-305.
5. Hoagland, D. R., and Arnon, D. I. 1950. The water-culture method for growing plants without soil. California Agric. Exp. Stn. Circ. 347.
6. Jenkins, S., and Kelman, A. 1976. Techniques for the study of *Pseudomonas solanacearum*. Pages 143-147 in: Proc. Int. Planning Conf. and Workshop on the Ecology and Control of Bacterial Wilt caused by *Pseudomonas solanacearum* L. Sequeira and A. Kelman, eds. University of California/AID, Pest Management and Related Environmental Protection Project: Berkeley. 166 pp.
7. Kelman, A., and Sequeira, L. 1965. Root-to-root spread of *Pseudomonas solanacearum*. Phytopathology 55:304-309.
8. MacNeill, B. H. 1955. *Colletotrichum* root rot of greenhouse tomatoes. Plant Dis. Rep. 39:45-46.
9. Price, D. 1980. Fungicides and the nutrient film technique. Acta Hortic. 98:277-283.
10. Resh, H. M. 1978. Hydroponic Food Production. Woodbridge Press Publishing Co., Santa Barbara, CA. 287 pp.
11. Schneider, R. W., Grogan, R. G., and Kimble, K. A. 1978. *Colletotrichum* root rot of greenhouse tomatoes in California. Plant Dis. Rep. 62:969-971.
12. Stanghellini, M. E., and Russell, J. D. 1971. Damping-off of tomato seedlings in commercial hydroponic culture. Prog. Agric. Ariz. 23(5):15-16.
13. Tuite, J. 1969. Plant Pathological Methods. Burgess Publ. Co., Minneapolis, MN. 239 pp.
14. Wittwer, S. H., and Honma, S. 1979. Greenhouse Tomatoes, Lettuce and Cucumbers. Michigan State University Press, East Lansing. 225 pp.