Control of Root Rot of Spinach Caused by *Pythium aphanidermatum* in a Recirculating Hydroponic System by Ultraviolet Irradiation

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ABSTRACT

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Greenhouse recirculating hydroponic systems facilitate continuous dissemination of introduced plant pathogens. Trials were conducted to determine the efficacy of ultraviolet irradiation of infested water for control of root rot of spinach caused by *Pythium aphanidermatum*. Seventy-two 2-wk-old spinach seedlings were transplanted into separate hydroponic chambers, which received either recirculated ultraviolet-treated or untreated water from a common source. Water was infested with encysted zoospores and oospores and was recirculated at a flow rate of about 124 L/min through an ultraviolet disinfestation unit. Within 7 days of transplanting, all spinach seedlings were dead in the chamber receiving untreated water. No plant death or root infection occurred in the chamber receiving ultraviolet-treated water.

Root diseases caused by *Pythium* spp. have been reported on various vegetable crops grown in recirculating hydroponic systems (2,3,7–11). Once introduced into such a cultural system, rapid and uniform dispersal of the pathogen is facilitated and catastrophic crop losses have occasionally been reported (2,3,8,11). No effective fungicides are currently registered for control of *Pythium* spp. on vegetable crops grown under recirculating hydroponic conditions; however, metalaxyl has been shown experimentally to be highly effective (2,7). Ultraviolet radiation has been proposed (1,5,6) as potentially effective for disinfestation of the nutrient solution, but no quantitative evidence on the control of a specific pathogen or disease has been presented.

Our objective was to test the effectiveness of ultraviolet irradiation in the control of *Pythium aphanidermatum* Edson (Fitzp.) in recirculating hydroponic systems. A preliminary report has been published (12).

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MATERIALS AND METHODS

Three separate A-frame cultural chambers were used (Fig. 1). Each A-frame had a reservoir that contained 760 L of a complete nutrient solution. Spinach (*Spinacia oleracea* L.) seedlings were reared in a nursery in peat pellets for 2 wk, then transplanted into holes cut in Styrofoam support boards (2.5 × 1.2 m × 2.5 cm). A support board containing 72 spinach seedlings was placed on each cultural chamber (Fig. 1) and the nutrient solution was misted, at 2.5-min intervals for 5 sec, onto the roots of the seedlings. *P. aphanidermatum* inoculum, which consisted of 15×10^6 encysted zoospores and 5×10^6 oospores, was introduced and thoroughly mixed into the reservoir of chamber 1 (Fig. 1). Twenty-four hours after infestation, infested water was recirculated at a flow rate of 282 L/min for 10 hr/day for seven consecutive days as follows: Infested water was first passed through a sand filter; one portion of the latter volume (about 157 L/min) was diverted into chamber 2 and returned to chamber 1, and a second portion (about 124 L/min) was diverted through an ultraviolet disinfestation unit (Model L-200, Ultraviolet Technology, Inc., Sacramento, CA) into chamber 3 and also returned to chamber 1 by a submersible pump. The disinfestation unit used in our study provided a minimum of 30,000 μW sec^2 cm^{-2} at 253.7 nm UV. Dwell time was about 3 sec.

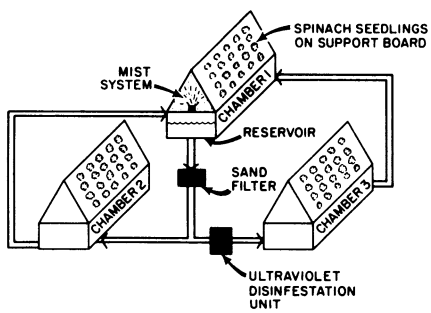

Fig. 1. Diagram of the recirculating hydroponic system used in studies on control of *Pythium aphanidermatum* by ultraviolet irradiation.

Plants were grown for 14 days but recirculation was discontinued after the seventh day. The percentage of plants stunted or dead was recorded daily over the test period. Root samples were collected randomly at periodic intervals from five spinach plants per support board, washed in running tap water for 10 min, plated on 2% water agar contained in petri dishes, and incubated at 27 C for 24 hr. The percentage of roots from which *P. aphanidermatum* was isolated was recorded. Additionally, ten 1-ml samples of the nutrient solution from each reservoir were collected periodically, plated directly on a selective medium (4), and incubated at 37 C. The number of colonies of *P. aphanidermatum* was recorded after 48 hr of incubation.

In a separate experiment, the infested nutrient solution in chamber 1 was recirculated as described, except the ultraviolet lights in the disinfestation unit were not turned on. All experiments were repeated once.

RESULTS AND DISCUSSION

The inoculum density of *P. aphanidermatum* in the 760-L reservoir of chamber 1 immediately after artificial infestation was 19.3 ± 4.0 propagules per milliliter. At the start of the recirculatory study, ie, 24 hr after initial infestation, the inoculum density in chamber 1 was 4.8 ± 2.0/ml and numerous spinach seedlings were already wilting. Twenty-four hours after the recirculation system was turned on, 97% of the spinach seedlings were dead and the fungus could be isolated from all roots sampled from chamber 1 (Fig. 2). After 4 days of recirculation, 24 healthy spinach seedlings were replanted on support boards in chamber 1. All seedlings died after 48 hr of incubation, indicating that sufficient and effective inoculum was still present in the artificially infested chamber. Eighty-seven percent of the seedlings in chamber 2, which received untreated infested water from chamber 1, died within 7 days after recirculation was initiated and *P. aphanidermatum* was consistently reisolated from roots of dead plants. No wilt or seedling death occurred in chamber 3, which received ultraviolet-treated water from infested chamber 1, and the fungus could not be isolated from roots of sampled seedlings during either the 7-day recirculation test period or the 7 days after recirculation was terminated. A repeat experiment gave similar results.

In a separate experiment, infested water was recirculated as described, except the ultraviolet lights in the disinfestation unit were not turned on. All spinach seedlings in the artificially infested chamber, as well as seedlings in chambers 2 and 3, died within 72 hr.

Recirculating hydroponic cultural systems that employ a common reservoir for distributing a nutrient solution both to and from numerous but separate production chambers are frequently employed in the greenhouse vegetable production industry. If a root pathogen is accidentally introduced into such a system at any location, rapid and uniform distribution is guaranteed. Fortunately, catastrophic losses to root diseases in commercial hydroponic culture of vegetable crops have not occurred widely in the industry, but where they have occurred, cultivation of the crop has been abandoned because of lack of effective control measures (2,7,11). Results of our study indicate that ultraviolet irradiation of infested reservoir water before distribution to separate production chambers was effective in preventing the spread of *P. aphanidermatum*. Whether such treatment would be effective against other root pathogens or species of *Pythium* is not known but is considered very likely. Ultraviolet irradiation would enable growers to continue cultivation of a susceptible crop in newly planted production chambers until plants in infested chambers are either harvested or eliminated. Further studies, however, are necessary to determine the size or number of ultraviolet disinfestation units necessary to disinfest contaminated water in large commercial operations where flow rates may exceed 124 L/min.

One problem that will be encountered after ultraviolet irradiation of the nutrient solution is iron chlorosis. Destruction of iron chelate after irradiation has been reported (5). Analysis of the iron content of the nutrient solutions we used dropped from 4.5 to 0.1 μg/ml after 24 hr of ultraviolet irradiation (Stanghellini et al, *unpublished*). However, iron can easily be injected into the nutrient solution after irradiation by using a portable proportioner.

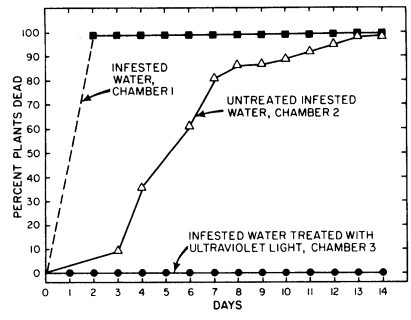

Fig. 2. Effect of ultraviolet irradiation on control of root rot of spinach caused by *Pythium aphanidermatum* in a recirculating hydroponic system.

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