Biology and Control of Soil-borne Pathogens in Greenhouse Production

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INTRODUCTION

Avoidance of root diseases was one of the primary motivating forces underlying the development of soilless agriculture. Although cultivation in soilless systems has resulted in a decrease in the diversity of root-infecting pathogens compared with conventional culture in soil, root diseases still occur. Most of the destructive root diseases in soilless culture have been attributed primarily to zoosporic, fungi-like species (oomycetes) in the genus *Pythium* and *Phytophthora.* Thus, knowledge of the avenues of pathogen introduction is requisite for maintaining a pathogen-free environment.

Potential and/or documented sources of pathogen introduction include the following : air, sand, soil, peat, water, and insects. Once root infection has occurred, disease management is often difficult because pathogen reproduction in the infected roots will provide a continuous (24/7) source of abundant new inoculum for rapid dispersal throughout the production system via the recirculating nutrient solution.

Disease management strategies following pathogen introduction have focused on elimination of the pathogen from the infested nutrient solution via filtration, ozonation, ultraviolet irradiation, thermal inactivation and/or the addition of specific biocides (fungicides, etc.) to the infested nutrient solution. Unfortunately, many of these management strategies are not efficacious, not registered for use in greenhouses or on specific crops, or not cost effective at the commercial level.

OBJECTIVES

A. Pathogen introduction via insects and snails

Adult shore flies and fungus gnats have been reported to function as aerial vectors of several plant pathogenic fungi, i.e., *Fusarium*, *Verticillium*, and *Thielaviopsis*. However, except for a single report of the aerial transmission of *Pythium aphanidermatum* by adult shore flies, there is no information regarding the role of these insects as vectors of other species of *Pythium* or *Phytophthora.* Thus, the specific objectives of our research were to (i) assess the potential of fungus gnats and shore flies to ingest and excrete propagules of *Phytophthora capsici*, *P. nicotianae*, *P. ramorum, Pythium aphanidermatum, P. splendens, P. sylvaticum* and *P. ultimum* and (ii) evaluate ingestion, excretion, and transmission of *Phytophthora ramorum* by brown garden snails. Various life stages of these insects, as well as snails, were allowed to feed on cultures of these pathogens. Viability of propagules of these pathogens was assessed following their excretion by these pests.

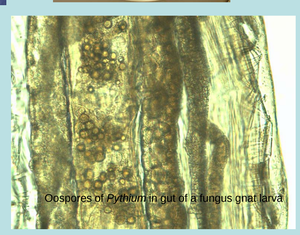

Adult shore flies feeding on an oomycete

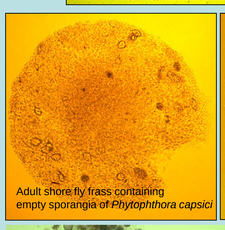

Fungus gnat larvae feeding on an oomycete

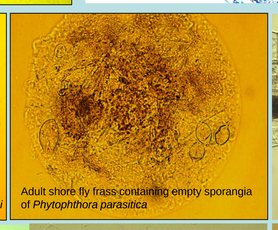

Snail feeding on an oomycete


Sporangia of *Phytophthora* in gut of a shore fly larva


Sporangia of *Phytophthora* in gut of fungus gnat larva

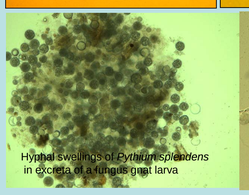

Oospores of *Pythium* in gut of a fungus gnat larva

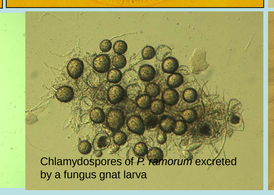

Adult shore fly frass containing empty sporangia of *Phytophthora capsici*

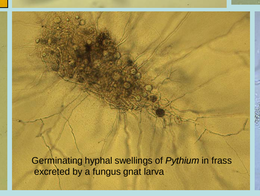

Adult shore fly frass containing empty sporangia of *Phytophthora parasitica*

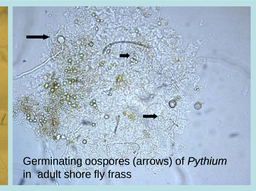

Fungus gnat larva excreting sporangia of *Phytophthora ramorum*


Empty and lysing sporangia of *Phytophthora* following excretion by a shore fly larva


Hyphal swellings of *Pythium splendens* in excreta of a fungus gnat larva


Chlamydospores of *P. ramorum* excreted by a fungus gnat larva


Germinating hyphal swellings of *Pythium* in frass excreted by a fungus gnat larva


Germinating oospores (arrows) of *Pythium* in adult shore fly frass

RESULTS and CONCLUSIONS: With the exception of oospores of *P. aphanidermatum*, adult shore flies are not capable of ingesting and excreting viable hyphal swellings, chlamydospores or sporangia of three species of *Pythium* and two species of *Phytophthora*. Further, adult fungus gnats do not feed on fungi. Thus, neither adult shore flies nor adult fungus gnats are likely to function as aerial vectors of these oomycetes. However, larval stages of both fungus gnats and shore flies are capable of ingestion and excretion of viable hyphal swellings of *P. splendens*, *P. sylvaticum*, and *P. ultimum,* as well as chlamydospores of *P. ramorum,* implicating them as potential vectors of these oomycetes. Additionally, snails were capable of ingesting and excreting viable sporangia and chlamydospores of *P. ramorum*. Although these greenhouse pests (larvae and snails) may not contribute to the rapid spread of these oomycetes compared to dispersal by adult flies, they may play a role in the initial introduction of the pathogen into a production facility via infested cuttings and horticultural substrates. Once introduced, these oomycetes could be dispersed rapidly throughout the production facility in the recirculating nutrient solution.

Publication: N. Hyder, M.D. Coffey, and M.E. Stanghellini. 2009. Viability of oomycete propagules following ingestion and excretion by fungus gnats, shore flies, and snails. Plant Disease 93:720-726.

B. Chemical amendments to the nutrient solution for disease control

We previously reported that N-Serve and Dwell (i.e., nitrification inhibitors), when added to the re-circulating nutrient solution in hydroponic systems, resulted in a significant increase in the total bacterial and indigenous fluorescent pseudomonad populations which, either directly or indirectly, coincided with the suppression of disease caused by a root-infecting zoosporic pathogen. In our ongoing search for additional and perhaps more efficacious amendments for management of zoosporic pathogens in re-circulating systems, we evaluated the efficacy of the following chemical amendments to the nutrient solution: zinc oxide, xylene, Actigard®, Neem, Perasan® and sodium salicylate.

All experiments were conducted in a greenhouse containing 18 two-sided recirculating hydroponic units (Figure 1) and used pepper as the susceptible host and *Phytophthora capsici* as the zoosporic pathogen (i.e., a worst case scenario).

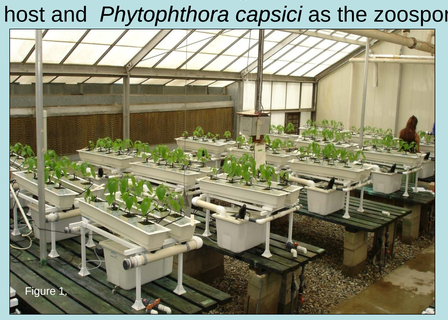


Figure 1.

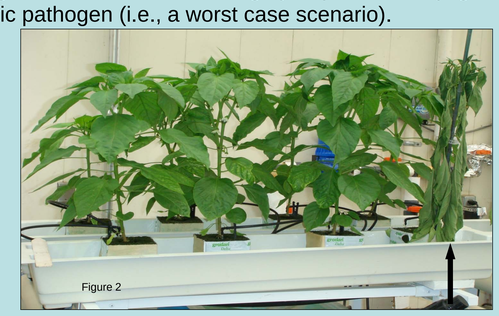


Figure 2

Each hydroponic unit consisted of two troughs that were connected to a common 50 liter reservoir. Pepper seeds were sown in Rockwool cubes and grown for ca. 30 days in a growth chamber at 30C with a 12 hr photoperiod. They were then transplanted into plastic pots containing a commercial peat-based potting mix or Rockwool blocks and placed in the hydroponic units (4 plants per trough, eight plants per hydroponic unit) in the greenhouse and grown for 2-3 weeks before treatment.

Each experiment consisted of three to five treatments, each with three replications per treatment. Treatments included noninoculated units, inoculated units and inoculated units in which the nutrient solution was amended with the various chemical amendments. One plant on one side of each hydroponic unit (Figure 2, arrow) was inoculated with *P. capsici.* This method of inoculation permitted us to evaluate pathogen spread via the recirculating nutrient solution subsequent to pathogen colonization and reproduction on the inoculated plant.

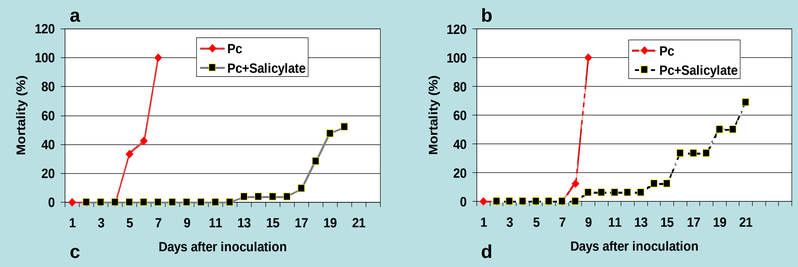
Chemical amendments were added to the reservoirs of appropriate treatments 2 days before inoculation. The final concentration of the various chemicals in the nutrient solution was: zinc oxide (2.5 ug a.i/ml)., Actigard (10 ug a.i./ml), Neem (10 ug a.i./ml), xylene (20 ug a.i./ml), Perasan® (50 ug a.i./ml) and sodium salicylate (100 ug a.i./ml). Chemicals were reapplied at weekly intervals.

Plant mortality data was recorded daily following inoculation. Additionally, the bacterial population in the recirculating nutrient solution was estimated by dilution plating onto a nutrient agar medium at 2-day-intervals following the addition of the chemical amendments.

RESULTS: With the exception of sodium salicylate (Figures 4 and 5), none of the other chemical amendments to the nutrient solution (i.e., Neem, xylene, zinc oxide, Perasan® or Actigard®) provided either consistent or significant control of the disease. All chemical amendments, except Perasan®, enhanced the total and the fluorescent bacterial population in the nutrient solution. However, the selective enhancement of the fluorescent pseudomonad population (which consisted of several biotypes) varied dramatically (0 to 87%) following each consecutive addition of sodium salicylate to the nutrient solution (Fig. 6). The fluorescent pseudomonad population may or may not have contributed to the observed sodium salicylate-mediated suppression of the disease.

Figure 5. Effect of chemical amendments added to the nutrient solution for the control of root rot of pepper caused by *Phytophthora capsici (Pc).*

Figure 4. Effect of sodium salicylate on the onset and severity of root rot and plant mortality caused by *Phytophthora capsici* (Pc) in four experiments.



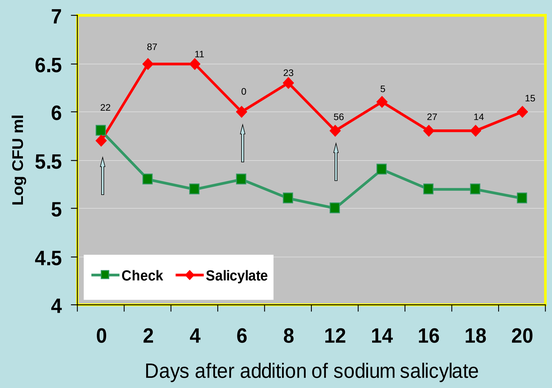


Figure 6. Population dynamics of bacteria in the nutrient solution in response to sodium salicylate amendment. Arrows indicate date of sodium salicylate application and numerals indicate the percentage of the enhanced bacterial population that were identified as fluorescent *Pseudomonas* spp.

Conclusion: **This study demonstrates, for the first time, the potential use of sodium salicylate as an amendment to the recirculating nutrient solution for the control of zoosporic root-infecting pathogens. The consistent delay in both the onset and the severity of disease achieved in the extreme pathosystem we used, i.e., peppers versus *P. capsici* - a worst case scenario (Fig. 4 and 5), suggests that even higher levels of disease management are probable in the more common and less destructive host-pathogen combinations which occur in commercial production of crops cultivated in recirculating hydroponic systems.**