Tracking Water Molds in Hydroponic Systems

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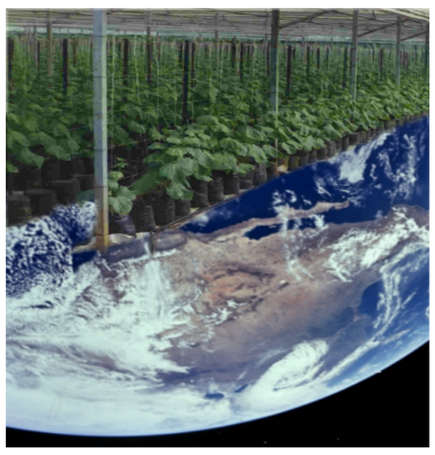


The greenhouse industry: a sustainable enterprise suitable for both environmental and space programs

Abstract

Understanding the differences within the rhizosphere in field crops and recirculating hydroponic systems is crucial in controlling root rot caused by *Pythium* and *Phytophthora* species. Hydroponic systems originally came about to eliminate many of the variables that contribute to disease in the field, but other variables may have been created in the process. With the development and widespread use of cost-efficient hydroponic systems, it is clear these pathogens possess a unique ability to survive and spread in them. It is not known how these pathogens survive in hydroponic solution, which should be investigated to create disease management techniques to fit the microorganism.

Little has been done on root disease epidemiology in hydroponic systems, leading to inefficient disease remediation and management. A reassessment of stress variables relating to the growth media is needed; factors that influence plant stress in soil systems are not necessarily the same in hydroponic systems. Conversely, *Pythium* and *Phytophthora* spp. should be similarly reassessment for the same reason to map an epidemiology of root rots in recirculating hydroponic systems.

This can extend the capabilities of commercial hydroponic systems and increase productivity. Identification of disease variables in recirculating hydroponic systems would allow a primary HACCP step from the food-processing sector to be applied, allowing commercial producers to identify and evaluate critical control points. This would increase the degree of control and management of *Pythium* and *Phytophthora* root rots. This potential is not limited to commercial production systems; a similar monitoring system would be beneficial where resources and money are limited, increased efficiency and reduced pathogen involvement is needed.

Introduction

Why it's important: The Industry. Crops associated with hydroponics are mainly vegetable and floral products, and are termed horticultural crops. The horticulture sector in Canada nets annual revenues of 3.4 billion dollars, 2 billion of this was made in exports while total vegetable production over a five-year span between 1993 and 1997 grew from $892 million to $997 million, a change of 22%[1]. Individual products such as hydroponically grown or greenhouse tomatoes within the same period grew from an annual economic yield of $38.6 million in 1994 to $98.7 million in 1996, a 31% increase over two years[2]. The greenhouse and hydroponics industry has been increasing at a steadfast rate over the past 10 years and if this trend continues, annual vegetable production figures will be more than $1216.34 million within the next couple of years. Applied to the total annual revenue for the horticulture sector in Canada, this represents an increase of over 35%.

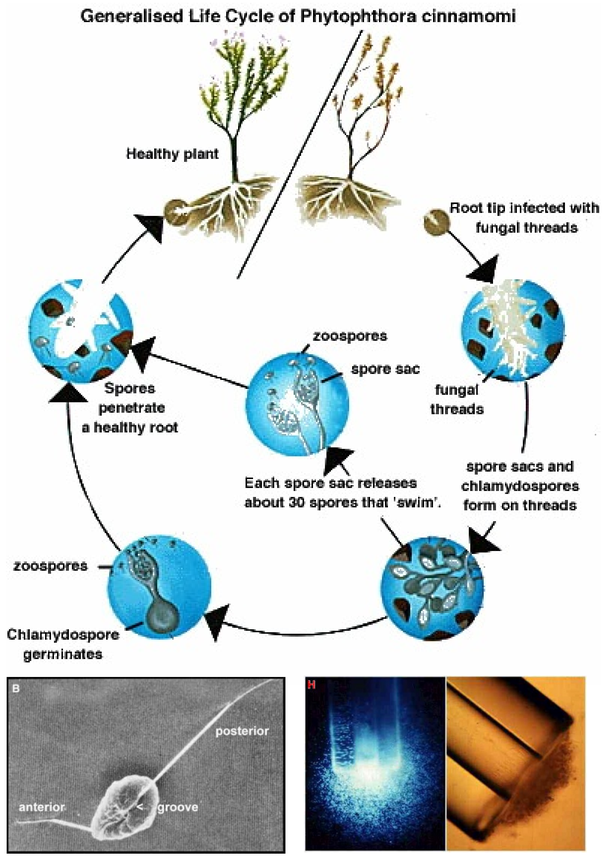
However, estimated yield losses attributed to *Pythium* and *Phytophthora* spp. can approach 30% of a normal hydroponic production, and can go unnoticed because of the uniformity and continuity of the crop setup[3, 4, 5]. In terms of the tomato example above, it can mean an annual loss of more than $29.6 million in 1996 dollars - a significant loss not restricted to this vegetable. This implies hydroponic systems are not realizing their full potential because of hidden yield losses attributed to these water molds.

The differences: Soil vs. Hydroponics. Crops in field soil are subjected to inclement weather and can often only be grown part of the year in Canada. The roots are reasonably protected and provided with sufficient oxygen and water through capillary dynamics caused by variable pore sizes created by soil aggregates. Bruehl (1987) found that the soil structure can effectively restrict *Pythium* and *Phytophthora* zoospores from spreading, unless sufficient flooding or water flow exists. By their nature, soils also contain an extensive population of soil microorganisms that compete with naturally occurring pathogens for resources[6]. *Pythium* and *Phytopthora* are considered minor pathogens in soil systems for these reasons and are often overshadowed by their foliar disease counterparts[5].

A combine harvesting field corn. Source: http://amslink.tierranet.com/combine.htm

A commercial hydroponic lettuce operation. Source: http://www.hydroponicsonline.com/

In contrast, crops in recirculating hydroponic systems are set up in greenhouses which provides an ecosystem that is not easily changed except by extreme outside temperature differences. Foliar diseases are less of a concern, however root pathogens are more highly involved in hydroponic crops because the plant nutrient solution is suited to the life cycle of these microorganisms. The nutrient solution allows *Pythium* and *Phytophthora* to access the roots of several plants with little or no microbial competition[7, 8, 9].



Top: While similar to *Pythium*, life cycles have not been mapped for hydroponic systems. Bottom left: a *Phytophthora* zoospore showing flagella. Bottom right: zoospore chemotaxis of *Pythium* towards capillary tubes filled with glucose and maple syrup. Source: http://helios.bto.ed.ac.uk/bto/microbes/zoospore.htm

Objectives, Materials and Methods

HACCP - as applied to recirculating hydroponic systems. Why use HACCP measures? Why not use IPM? A combination of the two may work better than either one alone. IPM concentrates on the pathogens[2] while HACCP is site-specific and considers locations and materials where potential contamination may occur[13]. Integrating these two programs would create a more effective site- and pathogen-specific disease management program geared towards root rots, a logical step since IPM measures have only been applied to plant diseases over the past 10-15 years[14] and have only been applied to hydroponic crops recently[2]. HAACP application of critical control points (CCP's) in an IPM context would be beneficial where water source, entry and exit points, inputs, materials, or transplants are suspect[15, 16]. An epidemiology of root diseases in recirculating hydroponic systems is needed to do this.

Methods for evaluating plant stress and tracking the water molds: A four-tiered plan would involve evaluating the nutrient solution, roots, individual plants and the entire crop within two phases: 1) materials at various stages of preparation prior to use, and 2) at various locations on site. Stresses on the crop will be measured as they appear accordingly to temperature and oxygen fluctuations in the ambient and rhizosphere environments. Plant stress can be measured using leaf chlorophyll content, plant height and yield, plant nutrient solution EC, pH, and dissolved oxygen content. Oospores within the roots can be detected with a method adapted from Epple et al., (1998), and roots and nutrient solution can be plated on media selective for *Pythium* and *Phytophthora* spp. as outlined by Jeffers and Martin (1986). There are other methods of zoospore and oospore detection, which should be investigated during the course of this project.

Discussion

The hydroponic industry is fast growing and shows potential for effective resource management and environmentally friendly land use. However, because of the hidden losses associated with *Pythium* and *Phytophthora* spp., a more aggressive and disciplined management program and a concise disease epidemiology is needed for recirculating hydroponic systems. This would use location rather than disease populations to contain epidemics. This attention to detail has the potential to increase the overall efficiency of the system by reducing the money, time and effort spent on reducing or controlling pathogen involvement. With modifications, this has applications where limited resources exist and increased yields are needed, for example, in less-developed countries or in the space program.

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Space station Mir seen against the Atlantic Ocean. Source: http://www.nasa.gov/gallery/index.html

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Understanding the differences within the rhizosphere in field crops and recirculating hydroponic systems is crucial in controlling root rot caused by Pythium and Phytopthora species. Hydroponic systems originally came about to eliminate many of the variables that contribute to disease in the field, but other variables may have been created in the process. With the development and widespread use of cost-efficient hydroponic systems, it is clear these pathogens possess a unique ability to survive and spread in them. It is not known how these pathogens survive in hydroponic solution, which should be investigated to create disease management techniques to fit the pathogen.

Little has been done on root disease epidemiology in hydroponic systems, leading to inefficient disease remediation and management. A reassessment of stress variables relating to the growth media is needed; factors that influence plant stress in soil systems are not necessarily the same in hydroponic systems. Conversely, Pythium and Phytopthora species should be subjected to similar reassessment for the same reason and an epidemiology of root rots caused by these species in recirculating hydroponic systems can be mapped accordingly.

This can extend the capabilities of commercial hydroponic systems and increase productivity. Identification of disease variables in recirculating hydroponic systems would allow HACCP principles from the food-processing sector to be applied, allowing commercial producers to identify and evaluate critical control points throughout the system. To do this, monitoring the occurrence of the pathogen within the system is necessary and methods on how to track the progress of disease occurrences should be evaluated. This would increase the degree of control and management of Pythium and Phytopthora root rots. This potential is not limited to commercial production systems; a similar monitoring system would be beneficial where resources and money are limited, increased efficiency and reduced pathogen involvement is needed.

Why it's important: The Industry
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However, estimated yield losses attributed to Pythium and Phytopthora species can approach 30% of a normal hydroponic production, and can go unnoticed because of the uniformity and continuity of the crop setup3, 4, 5. In terms of the tomato example above, it can mean an annual loss of more than $29.6 million in 1996 dollars - a significant loss not restricted to this vegetable. This implies hydroponic systems are not realizing their full potential because of hidden yield losses attributed to the water molds of the Pythium and Phytopthora species.

The differences: Soil vs. Hydroponics
Crops in field soil are subjected to inclement weather and can often only be grown part of the year in Canada. The roots are reasonably protected and provided with sufficient oxygen and water through capillary dynamics caused by varying pore sizes through the different soil layers. Bruehl (1987) states this same pore structure in some soils can effectively restrict Pythium and Phytopthora zoospores from spreading, unless sufficient flooding or water flow exists. By their nature, soils also contain an extensive population of soil microorganisms that compete with naturally occurring pathogens for resources6. Pythium and Phytopthora are considered minor pathogens in soil systems for these reasons and are often overshadowed by their foliar disease counterparts5.

In contrast, crops in recirculating hydroponic systems are set up in greenhouses which provides an ecosystem that is not easily changed except by extreme outside temperature differences. Foliar diseases are less of a concern because there is little wind movement to spread spores within a greenhouse, however root pathogens are more highly involved in hydroponic crops because the plant nutrient solution is suited to the life cycle of these microorganisms. The nutrient solution allows Pythium and Phytopthora to access the roots of several plants with little or no microbial competition7, 8, 9.

Project objectives
1) Map root disease epidemiology in commercial recirculating hydroponic systems
2) Determine specific indicators of stress that would preclude root rot
3) Design and implement a management program that incorporates elements of HACCP (Hazard analysis and Critical Control Points) and IPM (Integrated Pest Management) strategies.

Pathogens of importance: Pythium and Phytopthora species
Pythium and Phytopthora spp. are root pathogens which produce motile zoospores in combination with survival structures called oospores. These microorganisms are called water molds because they are most suited to aquatic environments and do not tend to spread in soil unless suitably damp or flooded conditions exist. No such control exists in hydroponic systems, which allows zoospores to disseminate freely and provides a vector through which they can infect more plants, particularly insidious within a recirculating or closed hydroponic system10. In addition to having this vector, these zoospores have a proven chemotaxic response to plant root exudates making them doubly suited to hydroponic systems7. While some species are specific in their targets and pathogenic abilities, most are unspecific and a large majority of those that infect vegetable crops are opportunistic pathogens, producing root rots when symptomless plants are stressed, often by temperature fluctuations11, 12.

Methods for evaluating stress and tracking the water molds:
A four-tiered plan would involve evaluating the nutrient solution, roots, individual plants and the entire crop within two phases: 1) materials at various stages of preparation prior to use, and 2) at various locations on site. Visible and measured stresses on the crop will be measured as they appear accordingly to temperature and oxygen fluctuations in the ambient and rhizosphere environments. Visible stresses would include visible detection of wilting, root rots and otherwise ill health of individual plants. These can be measured using variables such as leaf chlorophyll content, plant height, plant nutrient solution EC, pH, and dissolved oxygen content. Another variable that can be measured is the total yield of the crop. Oospores within the roots can be detected with a method adapted from Epple et al., (1998), and roots and nutrient solution can be plated on media selective for Pythium and Phytopthora species as outlined by Jeffers and Martin (1986). There are other methods of zoospore and oospore detection, which should be investigated during the course of this project.

HACCP - as applied to greenhouse hydroponic systems
Why use HACCP measures? Why not use IPM? A combination of the two may work better than either one alone. IPM measures often only come into play when problems first begin to arise, although there are provisions for pest monitoring before it becomes a problem2. HACCP anticipates the problem and works to prevent it from occurring in the first place through the establishment of a system that recognizes locations and materials where potential contamination or infection may occur15. The HACCP system can also monitor other hazards causing plant stress or phytotoxicity, which in combination with regular IPM strategies may prove to be unusually beneficial where recirculating hydroponic systems are concerned. Particular strategies of importance include those concerning critical control points and using a combination of biological, physical, cultural, mechanical, behavioral measures. Integrating these two programs would create a more effective site- and pathogen-specific disease management program geared towards root rots, a logical step since IPM measures have only been applied to plant diseases over the past 10-15 years16 and have only been applied to hydroponic crops recently2.
Possible CCP's within a recirculating hydroponic system would be based on water source, entry and exit points, inputs, materials, and transplants. Field applications of manure can pollute ground or well water17 and irrigation water has frequently been shown to contain Pythium18. Most of the inputs are in the form of chemical nutrients for the plant nutrient solution and should not be a cause of infection directly, but may cause expression of symptoms by causing plant stress by not providing enough or too much of a nutrient. Materials used within a hydroponic operation should be tested for cross-contamination, particularly rockwool, peat moss cubes and any transplant or structural material that comes in direct contact with the nutrient solution and the roots. These are just a few examples and are by no means a complete list.

Discussion
The hydroponic industry is fast growing and shows potential for effective resource management and environmentally friendly land use. However because of the hidden losses associate with Pythium and Phytopthora species, a more aggressive and disciplined management program is needed which uses location rather than disease progression or populations to ensure that spread is contained. This attention to detail has the potential to increase the overall efficiency of the system by reducing the money, time and effort spent on reducing or controlling pathogen involvement. With modifications, this has applications where limited resources exist and increased yields are needed.