A Risk Analysis of the Production of Hydroponic Baby Spinach with Respect to *Pythium aphanidermatum*

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Pythium aphanidermatum and Hydroponic Production

Pythium aphanidermatum is a water mold that can cause severe damage to crops through destruction of their root systems. It is of particular concern in hydroponic production systems because Pythium zoospores are mobile in water, and can quickly spread. Pythium affects a variety of crops, but spinach has been shown to be particularly sensitive to this pathogen (Bates, 1984). It is a leading obstacle to the commercialization of hydroponic spinach production.

A proven technique for growing spinach hydroponically is to change out the nutrient solution between crop cycles. Unfortunately this model for spinach production requires the added expense of disposing of the nutrient solution and disinfecting the growing surfaces. To allow re-use of nutrient solution, considerable research has been conducted into means of eliminating Pythium (and other nutrient solution borne pathogens.) Technologies that have proven effective have been heat (pasteurization) (Runia 2000), Ultraviolet radiation (Stanghellini 1984), Filtration (Tu 2005), and Sonication (Tu 2000). These systems have proven effective and could be implemented for a batch type production system where the nutrient solution required to grow a crop is treated after the crop is harvested, in preparation for re-use with the next crop.

Another technique particularly suited to baby spinach production is to maintain cool nutrient solution temperatures, and harvest the crop promptly at 16 days (Shelford, 2006) . Temperature suppression appears to slow the reproduction rate of Pythium (Katzman 2003) to a point where it does not have the opportunity to spread, provided the old infected roots are removed at harvest time. A further refinement of this technique is to spread the production of the spinach into two ponds. The first pond is for young plants up to 8 days old, which are then moved to a second pond for the duration of the crop cycle. Older infected roots no longer have the chance to release zoospores and contaminate the younger material in the first pond.

Objectives:

The overall objective is to utilize a risk analysis framework including risk assessment, risk evaluation, and risk management to find the optimal way to produce baby spinach hydroponically. Required steps are to:

•Develop a model for the propagation of Pythium aphanidermatum and the damage it causes as a function of temperature and time

•Develop a greenhouse energy balance model to determine expected pond temperatures based on climate conditions and typical greenhouse operational parameters

•Evaluate the impact of Pythium aphanidermatum on different hydroponic production strategies

•Compare the costs/reliability of selected strategies

•Recommend the most viable strategy

Production Strategies:

1.Continuous production, reuse untreated solution, no pond temperature controls
2.Continuous production, reuse untreated solution, pond temperature controls
3.Continuous production, new solution, no pond temperature controls
4.Continuous production, reuse untreated solution, no pond temperature controls, 2 pond system
5.Continuous production, reuse untreated solution, pond temperature controls, 2 pond system
6.Batch production, reuse untreated solution, no pond temperature controls
7.Batch production, reuse untreated solution, pond temperature controls
8.Batch production, reuse treated nutrient solution, no pond temperature controls
9.Batch production, reuse treated nutrient solution, pond temperature controls

Methods:

A combined greenhouse temperature, disease and growth model (Both 1996) will allow a comparison of how different production strategies will fare under variable climatic conditions.

Model of Pythium propagation in nutrient Solution:
Combines the temperature dependency relationship of Pythium propagation established by Katzman (2003) with observed progression of disease in 16 day crop cycle bench-top production.

Greenhouse energy balance model
Utilizes either real or simulated hourly environmental data for light, temperature and relative humidity to predict greenhouse conditions required for the disease and spinach growth model including:
- **Light level**
- **Aerial and Root zone temperatures**

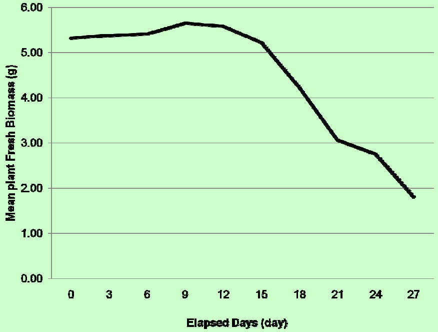
Impact of Pythium on Production strategies
The simulation model will be run on each of the different growth strategies
Recorded data will include the expected yields, loss to Pythium, and greenhouse operational parameters.
Sensitivity analysis of disease, production and other important parameters will be conducted

Comparison of costs/ reliabilities
From the greenhouse operational parameters and yields generated from the simulation model, relative costs of production (both in terms of energy, materials and labor) will be developed for each strategy

Recommend most viable strategy
The most cost effective strategy will then be recommended.
The risk analysis can be repeated for differing climatic conditions, to provide recommendations for locations other than Ithaca.

Results to date:

Model of Pythium Propagation:
- **Using data collected by Katzman (2003) on the effect of Pythium dose concentration, solution temperature and duration of exposure on harvest yield I plan to first develop a Pythium growth model.**
- **I will then compare this model to data we collected from both purposely innoculated, and observed Pythium outbreaks**



Observed uninoculated Pythium outbreak

Greenhouse Energy Balance Model
- **Written in Java for potential web publication**
- **Allows the implementation of variable greenhouse control strategies/setpoints including aerial and root zone temperature control (heating/cooling) and light control (supplemental and shading)**

Simulated Pond Temperatures
Ithaca 1988 dataset

References

Bates, M.L., and M.E. Stanghellini. 1984. Root Rot of Hydroponically Grown Spinach Caused by Pythium aphanidermatum and P. dissotocum. Plant Disease 68(11): 989-991.

Both, A.J., A.R. Leed, E. Goto and L.D. Albright. 1996. Greenhouse Spinach production in a NFT system. Acta Hort 440:187-192.

Katzman, L. 2003. Influence of plant age, inoculation dosage and nutrient solution temperature on the development of Pythium aphanidermatum in hydroponic spinach (spinacia oleracea L.) production systems. Doctoral Thesis Ithaca, NY.: Cornell University Library.

Runia, W.T., and J.J. Amsing. 2000. Lethal Temperatures of Soilborne pathogens in recirculation water from closed cultivation systems. Acta Hort. 544: 333-339.

Shelford, T.J., L.D. Albright, R.W. Langhans, and D.S. de Villiers. 2006 A Comparison of three Treatment Systems for the Suppression of *Pythium aphanidermatum* in Continuous Production of Hydroponic Babyleaf Spinach 2006 ASABE Annual Meeting Paper, 064020.

Stanghellini, M.E., L.J. Stowell, M.L. Bates. 1984. Control of Root Rot of Spinach Caused by *Pythium aphanidermatum* in a Recirculating Hydroponic System by Ultraviolet Irradiation. Plant Disease 68(12): 1075-1076.

Tu, J.C., and W.Z. Zhang. 2000. Comparison of Heat, Sonication and Ultraviolet Irradiation in eliminating *Pythium aphanidermatum* zoospores in recirculating nutrient solution. Acta Hort. 532: 137-142.

Tu, J.C., and B. Harwood. 2005. Disinfestation of Recirculating nutrient solution by filtration as a means to control *Pythium* root rot of tomatoes. Acta Hort. 695: 303-308

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