DISEASE MANAGEMENT IN CROPS PRODUCED IN RECIRCULATING HYDROPONIC SYSTEMS

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Long-term maintenance of health, vigor, and productivity is a major challenge in hydroponic vegetable production. Growers frequently are faced with decline in quality, yield, and profitability of cucumbers, peppers, tomatoes and other hydroponic crops due to invasion of roots by pathogenic and other deleterious organisms, accumulation of phytotoxic substances of microbial and crop origin in the nutrient solution, salt imbalances and other causes. At times, losses are catastrophic such as when root rot and wilting become severe and fruit production ceases following attack by *Pythium*.

In some production systems, problems associated with harmful microbes and toxic substances are countered in part by continuous or periodic discharge of used nutrient solution into the environment combined with replenishment with fresh nutrient solution. Discharging, however, can pollute ground and surface water with plant nutrients, pathogens, toxic substances, pesticides and other residual materials in hydroponic nutrient solutions, and can thus become a serious liability issue. Discharging and replenishment can also place heavy demands on supplies of fresh water, a further issue of public concern. The long-term answer is not to discharge, but rather practice continuous recirculation of the nutrient solution combined with remediation measures against harmful organisms and toxic substances.

In this article we provide a perspective of root disease and what can be done to manage root-infecting organisms in hydroponic crops. We will use *Pythium* as our main example of a root-infecting pathogen because it affects all crops in hydroponic systems. However, the principles apply also to *Fusarium*, *Verticillium*, ‘deleterious microbes’ on roots, and other pathogens.

How *Pythium* gets into the nutrient solution and starts an epidemic of root rot.

Various kinds of *Pythium* that flourish on root systems of hydroponic crops can easily be introduced into the plant nutrient solution on transplants, other living plants, dead plant materials, soil and insects, and on contaminated footwear and machinery. In some instances they can be present in the water supply, especially if this is from surface water. Resistant spores (oospores) of *Pythium* can survive from previous crops on surfaces of plastic tubing and other components of hydroponic systems.

Why root rot epidemics can be "explosive".

Explosive epidemics involve rapid development of root rot and secondary symptoms such as wilting in large numbers of plants in the greenhouse. They occur because *Pythium* is able to multiply at a fast rate on the roots and spread rapidly to other roots. Spread is by means of microscopic zoospores that are carried or swim in the nutrient solution and infect the tip portions of young growing roots. *Pythium* also spreads from root to root by means of cottony hyphae. In cucumber, *Pythium* builds up in enormous amounts on the slimy root exudates that accumulate and float on the surface of the nutrient solution. Massive invasion of roots of all ages by hyphae in the exudates lead to severe rotting of entire cucumber root systems within a few days (See Zheng, Sutton, and Yu, cited below.) New generations of zoospores and hyphae are produced more or less continuously.

Lack of microbial competition and antagonism favor pathogenic organisms in hydroponic systems.

Nutrient solutions in hydroponic crops lack abundant and diverse microbial populations (microscopic fungi, bacteria, animals) especially during the first 8 - 12 weeks after transplanting (See

Zheng, Sutton, Yu; cited below). Thus, *Pythium* and other pathogens in plant nutrient solutions are not faced with good levels of natural enemies and competitors, which in more natural environments (soils, plant residues) help keep populations of pathogens down. In other words, biological control of *Pythium* in root zones of hydroponic crops normally is poor or absent, an important factor contributing to the explosiveness of root rot epidemics.

Environmental stress factors predispose hydroponic crops to attack by root-infecting pathogens.

Stress conditions such as periods of high temperature, low levels of dissolved oxygen in the nutrient solution, low light intensity, and nutrient imbalance greatly increase susceptibility of hydroponic crops to attack by *Pythium*, *Fusarium*, *Botrytis*, and other pathogens. This predisposition of plants to disease by environmental stress factors is a principal factor contributing to severe disease outbreaks, especially of *Pythium* root rot.

MEASURES FOR DISEASE MANAGEMENT BASED ON INFORMATION PRESENTED SO FAR:

1. Sanitation, and sterilization of materials, equipment, and surfaces in the greenhouse should be rigorous.
2. Much emphasis should be placed on producing pathogen-free transplants. It is not enough that roots of transplants appear healthy; plants without symptoms (such as brown roots) can easily harbor *Pythium*. ONE diseased transplant is enough to start an epidemic of root rot in a hydroponic system.
3. Maintain good insect control.
4. Consider filtering water from outside sources (eg. through sand), especially if it is surface water.
5. Regulate the microclimate and conditions of the plant nutrient solution so as to avoid or minimize predisposition of crops to disease. That is, avoid stress conditions as much as is practical. Many growers have recognized the value of oxygenation of the nutrient solution, especially in warm weather. Temperature of solutions should be below 27^{o}C when possible.

Remediation treatments of nutrient solution as it recirculates outside the crop zone.

Considerable attention has been given to inactivating, killing, or removing spores of *Pythium*, *Fusarium*, and other pathogens from the nutrient solution as it recirculates outside the crop zone. Physical methods include sand or lava rock filtration, ultrasound, heat, and ultraviolet (UV) light, some of which are discussed elsewhere in this Conference. At the University of Guelph, we have conducted detailed studies of the UV doses needed to inactivate different kinds of spores of *Pythium*, and *Fusarium* in water and hydroponic nutrient solutions (see Sutton et al., cited below.) Generally, doses of 40 to 50 mW.s/cm^2 are sufficient to destroy almost all of these kinds of spores. There is little question that spores of pathogens can easily be destroyed or removed from the nutrient solution as it recirculates outside the crop, whether by a UV apparatus, filtration, or other means.

What is unclear, however, is the impact of such treatment on pathogen populations and disease **in the root zone** of the crop. In our studies in growers' greenhouses, killing of spores that were in nutrient solution recirculating outside the crop only marginally reduced the progress of root disease and only slightly promoted yield. Much more research is needed to fully understand the value of UV and filtration treatments as remediation measures against pathogens and also against phytotoxic substances.

Protection in the root zone.

Besides remediation of nutrient solutions against pathogens and toxic substances, more direct protection of roots generally is needed to fend off *Pythium* and other pathogens. There are several possible options:

1 Use of beneficial microbes (discussed below).

2 Use of chemical agents.

Various surfactants, silicates, oxidants (H_2O_2, O_3, chlorine) and fungicides have been evaluated, chiefly in North America and Europe, but all have disadvantages (eg. not very effective, phytoxicity, practical shortcomings, costs, use registration). Nonetheless, some may have a role in integrated disease management, and other good possibilities so far unimagined or untried almost certainly exist.

3 As mentioned above, minimizing environmental stresses is extremely important.

Taking advantage of beneficial microbes.

There is now good experimental evidence to indicate that it is possible to utilize selected microbes to achieve the following in hydroponic crops:

- protect roots against pathogens and other harmful organisms.
- induce systemic resistance in plants so as to protect foliage against diseases such as powdery mildews and *Botrytis*.
- promote plant growth and productivity (independent of effects on disease; i.e. in healthy as well as diseased plants).
- sanitize nutrient solutions so as to destroy unwanted microbes, prevent mucilage accumulation, break down dead roots, and destroy phytotoxic substances.

An example of the experimental evidence is given in Zheng, Sutton, and Yu (cited below) in which two microbial agents controlled *Pythium* root rot in hydroponic cucumbers for about 90 days after transplanting (to our knowledge the longest control period yet achieved). The agents also induced resistance to powdery mildew (no mildew developed in treated plants, but was severe in untreated plants), and destroyed the cucumber root mucilage (which *Pythium* thus could not use as food).

Intensive research is now needed on formulating beneficial microbial communities that are self-sustaining (or can easily be sustained artificially) in the root zone, and which serve to achieve A-D above. The goal is to develop measures that are effective throughout the life of each kind of hydroponic crop. This is a ‘tall order’, but could well be possible given sufficient attention in laboratories and greenhouses. Integration of the use of beneficial microbes with other remediation treatments such as exposure of nutrient solutions to UV radiation and filtration of the solutions should not present practical difficulties and may well optimize the health of hydroponic crops produced in systems with recirculating nutrients or other technology.

Disease Management Summary

- Very thorough and adequate sanitation in the greenhouse.
- Use of pathogen-free transplants.
- Maintain adequate levels of dissolved oxygen (5-7 ppm or 11-14%).
- Maintain stress-free environmental conditions.
- Consider remediation of nutrient solutions by UV radiation and filtration as components of disease management programs.
- Keep aware of advances in biological remediation technology.
- KEEP AHEAD OF DISEASE.

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