Greenhouse and Nursery Water Treatment Information System

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UV LIGHT

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Background

Ultraviolet (UV) light treatment is a chemical-free method of water disinfection which uses exposure to a specific UV wavelength at a specific bulb power to inactivate microorganisms. On the electromagnetic spectrum, UV light consists of radiation with a shorter wave length than visible light, and as such it possesses higher energy. UV radiation with shorter wavelengths can be harmful to biological structures, and it is radiation in the UV-C spectrum that is used for killing pathogens. Of the 240-280nm range that constitutes UV-C radiation, 254nm is the wavelength most commonly used for disinfection purposes. This radiation destroys microorganisms (e.g. bacteria, mold, and viruses) through a photochemical reaction in which it reacts with the genetic information of the microorganism, disrupting this information and causing loss of reproductive capability and death.

The effectiveness of UV in pathogen destruction is greatly affected by water clarity. Decreased clarity in irrigation water will greatly decrease efficacy of UV treatment as incoming radiation will be reflected off or absorbed by non-pathogen particles in the water. This will greatly decrease the amount that reaches pathogens. The recommended water turbidity (cloudiness) for optimum UV treatment efficacy is < 2 nephelometric turbidity units (2 NTU). Light transmission rates (inversely related to turbidity) of recycled irrigation water are often much lower than the recommended rate, especially in nurseries (Stewart-Wade, 2011).

Application method

Use of UV light for irrigation water treatment requires the installation of a UV treatment system, which must be professionally installed by a company familiar with UV treatment for horticulture. In these systems, water travels through a cylindrical vessel and is treated by light from UV lamps mounted within the vessel. The UV light is applied at a particular power strong enough to destroy the microorganisms in the water.

Safety and handling information

UV lamps should be shielded to prevent radiation from escaping to the surrounding space.

Critical Levels for Pathogens

The optimum UV light wavelength to treat microorganisms is 254 nm, which destroys the genetic information of bacteria, viruses and mold. Pathogens must be exposed to the light at different powers. Refer to the below table for a list of power levels required to remove different pathogens (the ranges of power listed for some were compiled from 2 conflicting sources). Overall, a general guideline for disinfection is applying a power of 100mJ/cm^2 for fungi and 250mJ/cm^2 for complete disinfection including viruses (Runia, 1995).

Microorganism	**Propagule**	**Wavelength (nm)**	**Power of UV Light Dosage (mJ/cm^2)**
Bacteria (Fisher, 2011)		254	3.5-26.5
Tomato mosaic virus (Runia, 1994)	Virus	254	100 (low pressure lamp, 50% drainwater + 50% rainwater) 277 (high pressure lamp, drainwater) 106 (high pressure lamp, 50% drainwater + 50% rainwater)
Fusarium oxysporum (Runia, 1994)	Conidia	254	70 (low pressure lamp, 50% drainwater + 50% rainwater) 84 (high pressure lamp)
Pythium ultimum (Mebalds et al., 1996)	Spores	254	40
Phytopthera cinnamomi (Mebalds et al., 1995)	Spores	254	43
Colletotrichum capsici (Mebalds et al., 1995)	Spores	254	31
Alternaria zinniae (Mebalds et al., 1995)	Spores	254	850
Phytophthora citrophthora (Banihashimi et al., 2010)	Zoospores	248	10 (high powered, pulsed UV)
Phytophthora nicotianae (Banihashimi et al., 2010)	Zoospores	248	30 (high powered, pulsed UV)

Phytophthora capsici (Banihashimi et al., 2010)	Zoospores	248	30 (high powered, pulsed UV)
Radopholus similis (Amsing and Runia, 1995; Stewart-Wade, 2011)	Nematode	254	100 (did not cause mortality but prevented infection of roots)

The values above are for water with high clarity. As such, if proper measures are not taken to control water clarity, required UV power will be higher than those values listed.

Effect on plants

Treatment with UV will not affect plants as, unlike chemical treatments, it does not permanently alter water in any way outside of pathogen destruction (ie. has no residual effect).

Monitoring

All that must be monitored and controlled in a UV system is the power of the lamp, which is monitored and controlled by the installed system itself. However, because the efficacy of UV treatment is highly dependent on water turbidity, monitoring of turbidity using a turbidity meter is recommended (a description of turbidity meters can be found here: http://water.epa.gov/type/rsl/monitoring/vms55.cfm). The turbidity meter used must be reliable for the turbidity range of interest (irrigation water must be <10 NTU, but for UV treatment water should be <2 NTU; Fisher, 2011).

In combination with other technology

UV treatment is often combined with technologies that have a residual effect (ie. ozone, copper, hydrogen peroxide) in order to improve sanitation and algae removal further down the irrigation system. Combining UV treatment with use of an oxidizer such as ozone or hydrogen peroxide is especially effective as when UV light reacts with ozone or hydrogen peroxide it degrades the original compounds and produces hydroxyl radicals, which are strong oxidizers and more effective for sanitation than ozone and hydrogen peroxide themselves. However, this combination may be very costly, especially with the combination of ozone and UV, as both require costly, specialized equipment.

Because the efficacy of UV treatment is highly dependent on water clarity, pre-filtration of water is necessary. The number and fineness of filters required will depend on how “dirty” the water source is (see section on filtration). Unfortunately, because low water clarity is mainly a result of high dissolved solid content, pre-filtration (even to as fine as 5 microns), often does not help improve clarity in any significant way (Mebalds et al., 1996). Filtration on the level of a nanofiltration or even reverse osmosis (<0.01 micron) would be required to remove these small particles (Health Canada, 1991). Because of the high costs of these fine filtration systems, they may not be economically viable.

Cost for Technology

The use of any water treatment technology is dependent on the size of the production facility and the amount of water used. For UV treatment technology, operating costs constitute the cost of energy required to power the bulb, and as such are dependent upon local energy costs. Below are tables that summarize the average water consumption and cost of operating this technology for a small, medium and large facility. Capital costs of the UV system will likely depend on the extent of monitoring and control provided by the system itself, as well as the size of system required, and can range from $22,000 to $70, 000.

Size of Production Facility	Water Usage (litres/day) Greenhouse[1]	Water Usage (litres/day) Nursery[2]
Small	29,263 – 37,857	700,993 – 2,103,001
Medium	33,560 – 134,244	1,401,997 – 3,219,732
Large	117,057 – 151,431	1,609,854 - 4,829,610

Size of Production Facility	Operation Cost Greenhouse (per day)[3]	Operation Cost Nursery (per day)[3,4]
Small	$0.5-4	$36+
Medium	$0.5-7	$73+
Large	$0.5-7.60	$84+

[1]Flowers Canada Growers. (2011). Website: http://flowerscanadagrowers.com
[2]Canadian Nursery Landscape Association. (2011). Website: www.canadanursery.com/[3]Ranges have been estimated from a survey of companies and are only intended to give a rough idea of cost. To determine exact costs for your system, please contact a supplier.
[4]Nurseries usually do not need to treat all their water, so nursery costs are likely overestimates.

Costs- Maintenance

UV lamp bulbs will need to be replaced regularly, and the UV system generally has an alarm to indicate when replacement is required. While bulbs can last up to 10, 000 hours, they tend to degrade over time, resulting in a decreased UV output and decreased efficacy. Rate of loss will depend on the bulb, but losses of 10% after 1000 hours of operation, or up to 35% after operation for a year have been reported (Stewart-Wade, 2011).

The quartz tube within which the UV bulb is held must be cleaned regularly (3-6 months, depending on water quality) to remove accumulations of materials that may block UV radiation, such as calcium deposits. A vertical PVC pipe filled with acid can be used to clean the quartz tube (Fisher, 2011).

Overall, annual maintenance costs are approximately $1000-2000. For specific information on these maintenance requirements, as well as other maintenance requirements, the owner's manual of the purchased system will need to be consulted.

Pros and cons

Pros:

- Not corrosive or otherwise hazardous, to workers or the environment
- Effectiveness is not pH dependent
- No risk of accumulation of chemicals to phytotoxic levels
- Typically low operating cost

Cons:

- The lack of residual effect of UV can be problematic. Disease outbreak downstream of the UV treatment cannot be controlled without the addition of some form of residual treatment method (ex. ozone), which can be expensive
- Effectiveness is highly dependent on water clarity, and as such it is much more reliant on filtration than other treatment methods. Very fine levels of pre-filtration may be required, which can be costly
- Installation costs are high. Operation costs are typically low but can be costly depending on the amount of water being treated and as such the amount of energy being used
- Regular replacement of bulbs required, which can be costly. To avoid disease outbreak, lamps must be monitored

Summary

Overall, UV treatment can be used to effectively control plant pathogens in recirculating or non-recirculating irrigation systems, without risk of phytotoxic or other hazardous effects. Initial installation is fairly costly, and operation costs depend on the amount of energy being used which in turn depends on the amount of water being treated. As such, this treatment method may not be suitable for large production facilities with large areas susceptible to disease. As well, UV treatment may not be the most effective method for treating water in nurseries, where water runs over ground and tends to accumulate dissolved solids that will limit effectiveness.

Suppliers

Some examples of suppliers of UV systems include:

Producer	**Producer website**
Siemens	http://www.water.siemens.com/
ProMinent	http://www.prominent.ca/Home.aspx
Aquafine	http://www.aquafineuv.com/
HortiMax	http://www.hortimax.com/ http://www.acrobatcontrols.com/hortimax.htm
Priva	http://www.priva.ca//en/

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