GROWING KNOWLEDGE

Series content is coordinated by Dr. Jay Pscheidt, professor of botany and plant pathology at Oregon State University in Corvallis, Oregon.

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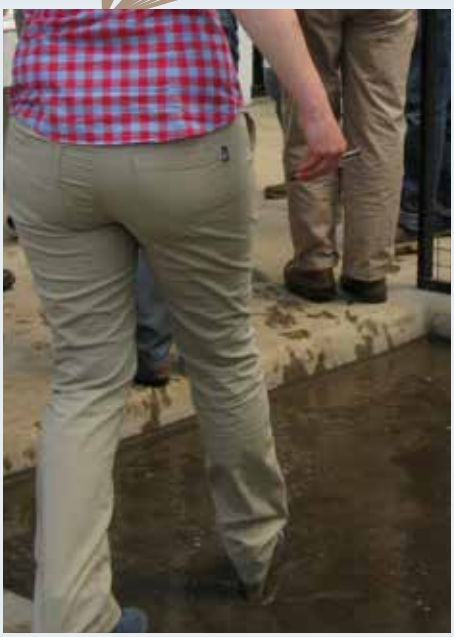
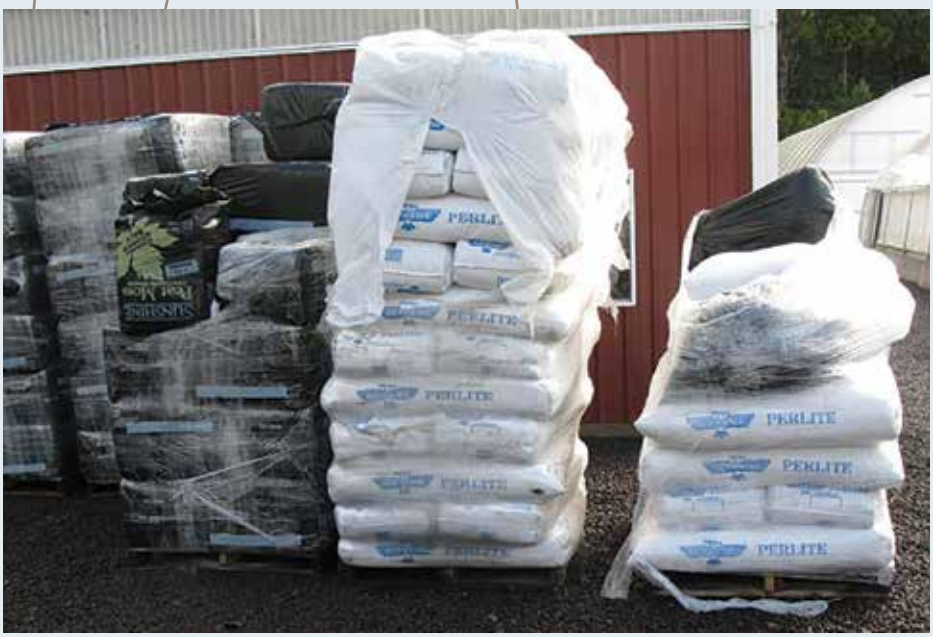




Footbaths containing disinfectant (*left*) will not totally eliminate all pathogens, but they will greatly reduce their numbers on shoes that have been brushed free of soil. *Right*: Bagged media should be kept off the ground to minimize the chance of picking up soil-borne pathogens. Preventing pathogen introduction into a facility is the main benefit of an effective sanitation effort.

Disinfectants: In search of a silver bullet

By Melodie L. Putnam & Luisa Santamaria

AS PLANT PATHOLOGISTS, we often encounter growers at facilities plagued by recurring disease. There are really only two reasons diseases persist within a site: the pathogens responsible have not been eradicated, or they are continually re-introduced. Both problems can be addressed by employing stringent sanitation measures.

Broadly, sanitation is the prevention of disease. This can be done by disinfecting surfaces, removing diseased or contaminated materials, establishing sanitation protocols and educating the staff to follow these protocols, and monitoring for lapses. The principles and particulars of an overall sanitation strategy have been thoroughly described (see Resources at the end of the article).

Growers, in attempting to implement recommendations regarding sanitation, often have very pertinent questions about specifics not mentioned in general suggestions. One of the most frequent questions we hear regarding sanitation is: "What is the best product to use for disinfecting tools, benches and greenhouses?"

This is a complex question with no single answer. Factors influencing the "which is best" question include the type of pathogen involved, contact time, the surface to be treated, the storage or use conditions of the diluted product, how hazardous the product is for people exposed on a daily basis, and the cost.

It is important to keep in mind that even the best disinfectants available for use in greenhouses will not eradicate 100 percent of all organisms under most use conditions. This is because disinfectants that are safe to use have differing abilities to kill different pathogens.

Oxidizing agents

Oxidizing agents such as hydrogen peroxide, peroxyacetic acid and products such as Virkon® S are effective against bacteria, less so against fungal spores and variable against viruses.

A recent study tested multiple products for prevention of Pepino mosaic virus, Potato spindle tuber viroid, Tomato mosaic virus and Tobacco mosaic virus. The test used viruses and viroids in pulverized plant tissue, which was then placed in disinfectant. The researchers found 2 percent Virkon S was best overall,

followed closely by 10 percent household bleach. However, neither product was able to prevent disease when a scalpel dipped in the disinfectant/pathogen suspension was used to make a wound on healthy plants. This means if cutting tools are disinfected with either Virkon S or bleach, but covered with sap or other plant debris, then the product may not be effective.

Peroxyacetic acid, one of the ingredients in ZeroTol 2.0 and Phyton X3, will inactivate bacteria, fungi and yeasts within five minutes when used at 100 ppm. However, if any organic matter is present, such as plant sap or potting mix, the disinfecting power is greatly reduced. We have found in tests with pure cultures that ZeroTol 2.0 will kill the crown gall bacterium (*Agrobacterium*) and the leafy gall bacterium (*Rhodococcus fascians*) from both steel and plastic surfaces, but there is no residual effect.

Quaternary ammonium

Quaternary ammonium (QA) compounds such as Physan 20, Green-Shield® and KleenGrow™ are more effective against gram-positive bacteria than gram-negative ones (see sidebar).

In our tests, one QA killed *Rhodococcus* (gram positive) but not *Agrobacterium* (gram negative) in pure culture assays. In addition, the product was unable to eradicate *Agrobacterium* from plastic or steel surfaces. This means QAs would not be the disinfectant of choice where crown gall is the problem.

Products containing QA compounds do not kill fungal spores, although they may help prevent spore germination. Quaternary ammonium compounds have very little effect against viruses and are not recommended for that use.

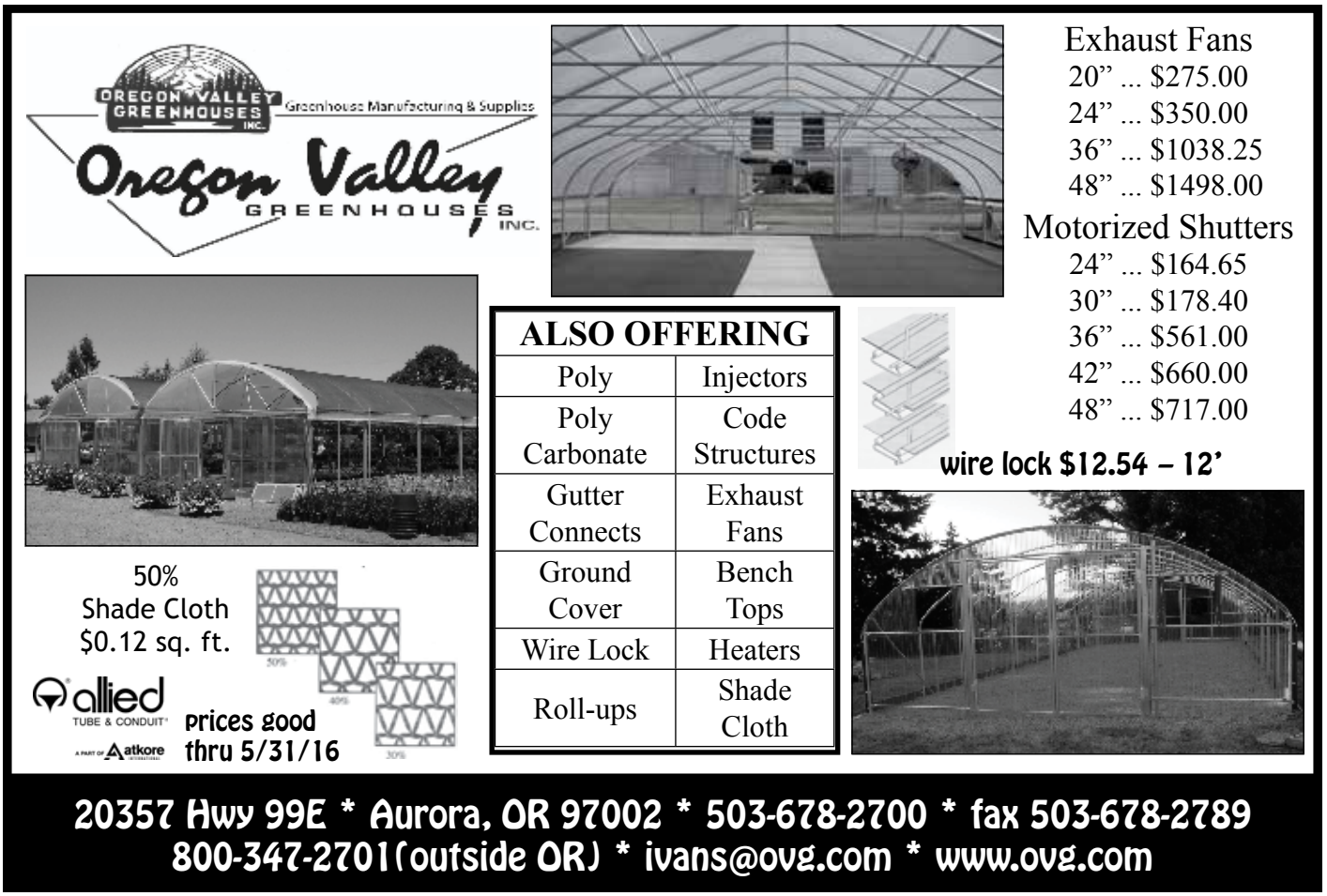
The advantage of the QA compounds is that they are effective at high temperatures and are relatively stable, but are adversely affected by very hard water and are inactivated by sap, other organic matter and anionic detergents. They also have no residual activity.

Some people are sensitive to the QAs and will break out in rashes upon exposure to the products.

Alcohols

Alcohols (ethyl alcohol, isopropyl alcohol) are quite effective against all plant pathogenic bacteria. They have some activity against fungal spores and some viruses, but are not the best choice for the latter. Alcohols should be used at 60–95 percent concentrations, and items must be fully submerged to be effective. The effective contact time varies, depending on the concentration used and the target pathogen.

In one study, a five-minute soak in isopropyl alcohol was not sufficient to kill all



fire blight bacteria on contaminated blades. Ethyl alcohol seems to have a better spectrum of activity at the concentrations given above. The flammability of alcohols makes them a hazard to use. They also evaporate quickly in warm greenhouses.

Sodium hypochlorite

Sodium hypochlorite (liquid bleach) is a relatively inexpensive product. It works equally well against bacteria, fungal spores and viruses, given a long enough contact time. However, the disinfecting activity decreases with an increase in pH, and the corrosiveness of bleach to metal is well known. A bleach solution must be made up fresh, prior to use (see below), and all items must be well submerged. Bleach is probably best used for disinfection of scrubbed pots and trays; it is not specifically registered for use in disinfecting greenhouses.

Disinfection requires sufficient contact with the surface being treated. Wooden benches, concrete blocks and concrete floors are porous and contain cavities in which the pathogens can not be reached by the disinfectant. Even cutting tools that appear smooth, such as clippers, will have microscopic cavities in which microbes can persist, especially if the tools are worn. This is one reason why brief sprays or dips are ineffective.

Having the tools industrially coated with a polymer, such as that used in non-stick kitchen pans (e.g., Xylan), will result in a smooth surface. Polymer-coated tools have been found to be more reliably disinfected. These coatings have the advantages of reducing friction during use. They are resistant to chemicals and corrosives, and easier to clean prior to disinfection.

Many disinfectants, as mentioned above, are inactivated by organic matter. Fertilizer salts may also affect efficacy of some products. This is why it is imperative to clean all visible debris and films from surfaces to be treated. Power washing with a detergent is a great way to prepare benches, floors and walls for disinfection.

Shelf life

Disinfectants vary in shelf life once diluted. For example, chlorine bleach loses half of its effectiveness two hours after the working solution was made (e.g., the half-life is two hours). This means that to be most effective, the solution must be prepared immediately before use.

Sunlight, fluctuating temperatures, pH and hardness of the water used to dilute a disinfectant can all adversely affect the ability of a product to function as it should.

To address this problem, we conducted an initial investigation to assess the efficacy of two commonly used disinfectants applied to plants: Physan 20 and ZeroTol 2.0. To reproduce real-world nursery conditions, these disinfectants were diluted to working concentrations, stored under different conditions, and tested over time. The goal was to determine at what point and under what storage conditions (varying light exposure and temperature) the efficacy of these products began to decrease.

A significant decrease in efficacy was found after 48 hours for ZeroTol 2.0. Although it was expected that Physan 20 would remain effective longer than ZeroTol 2.0, it was surprising to find that the former would maintain relatively high levels of efficacy over the course of one month. Unfortunately, product labels do not always have information as to when the product should be used after dilu-

Two groups of bacteria

Traditionally, bacteria are divided into two large groups, based on their cell wall composition: gram negative and gram positive. On a practical basis, knowing which bacteria you have will be helpful in selecting the most effective disinfectants, since the two types of bacteria may respond differently to products. A confirmed diagnosis of disease will help you select the most effective product.

Gram-negative bacteria
Agrobacterium
Dickyia
Erwinia
Pectobacterium
Pseudomonas
Ralstonia
Xanthomonas

Gram-positive bacteria
Curtobacterium
Clavibacter
Rhodococcus
Streptomyces

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tion, but check to see that you are using the product properly.

Relative effectiveness of selected disinfectants to pathogens*

	Oxidizing agents (hydrogen peroxide, peroxyacetic acid)	Quaternary ammonium compounds	Alcohols (ethyl, isopropyl)	Sodium hypochlorite (bleach)
Bacteria: gram positive	Good	Very good	Very good	Good
Bacteria: gram negative	Good	Good	Very good	Good
Fungal spores	Limited activity	Limited activity	Limited activity	Good
Viruses	Variable	Limited to none	Variable	Good

*Information was taken from the veterinary literature. Adapted from: Center for Food Security and Public Health, Iowa State University.

Other measures to control disease

Disinfectants are only part of an effective sanitation effort. There are some minimum standards that should be a routine matter in all greenhouses.

General sanitation measures will help reduce the need for pesticides. Dead plants, plants with vascular disease or root rots, and heavily spotted plants should immediately be removed from the greenhouse as soon as noticed. Any plant debris or potting mix associated with the infected plants should be swept up, placed in a closed container, removed from the house and buried, burned or otherwise destroyed.

Shoes can track in soil containing pathogens and should be cleaned before entering a greenhouse. At a minimum that means brushing soil from shoes. Footbaths or mats containing a disinfectant should be positioned at each greenhouse entry such that people must walk through them to enter. Footbaths will not totally eliminate all pathogens, but will greatly reduce their numbers on shoes that have been brushed free of soil. Change the disinfectant daily or when it first becomes visibly soiled. If footbaths are not possible, offer disposable boots to anyone entering a greenhouse.

Hand-washing can minimize pathogen spread. Hand-washing stations equipped with clean water and soap should be used prior to entering greenhouses. Clean tools are as important as clean hands; tools should be disinfected frequently, including watering wands. Do not allow hose ends or nozzles to contact the ground, and when hand watering, keep the hose end above the plant canopy. Some bacteria can be

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picked up on nozzles and carried to other plants. Do not drag hoses and other tools along floors, where infested soil and plant debris can be moved to clean surfaces.

Trucks and vehicles that have been used in the field should not be allowed in or around greenhouse production facilities without prior cleaning. This is especially true for backhoes used to mix or move potting media that has not been treated for pathogens prior to use. Forklifts and other vehicles used inside greenhouses should have tires brushed free of soil and debris before entering the house. Cleaning should take place where field soil will not be tracked or washed into houses. Having a large "foot" bath over which the tires must pass to enter the greenhouse will help to reduce entry of pathogens.

Continuing education is another part of a successful prevention program. An effective disease management system should include educational support for workers. By understanding the pathogens that cause disease, growers and workers are better able to manage problems at an early stage. Growers should ensure that all employees are properly educated in company protocols for pest and disease management practices. This should be followed by a regular assessment of procedures to ensure they are being properly followed. Early detection of plant diseases and pests is a critical component of effective sanitation and preventive measures.

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Resources

Sanitation guidelines for management of pests and diseases of greenhouse vegetables. 2014. (Ontario Ministry of Agriculture, Food and Rural Affairs). www.omafra.gov.on.ca/english/crops/facts/14-033.htm

Systems Approach — Safe Procurement and Production Manual. 2012. www.oan.org/systemsapproach.