



Greenhouse and Nursery Sanitation

Tools, Equipment, Workers, and Visitors

At A Glance

Prevention is the key to good pest management. Adhering to sanitation as a primary method for reducing the introduction and spread of weeds, insect pests, and diseases is essential in nursery and greenhouse environments. Using clean and well-maintained tools and equipment, and having consistent sanitation practices, ensures that pests are not spread through these pathways. Reducing the movement of non-sterile equipment, vehicles, and people will limit the spread. Providing training and having a protocol for employees to follow sanitary practices is an essential component of an effective, holistic sanitation-management plan.

One of the most common mechanisms for pathogens to spread is via contamination of equipment, tools, and humans. Fungi, bacteria, and some viruses are easily transmitted to the surfaces of equipment (e.g. plant sap, debris). Ensuring clean tools and equipment will help reduce the spread and incidence of plant pathogens. The clothing and bodies of workers and visitors, as well as any vehicles they bring onto the property, are also potential sources of pathogens and pests.

Tools and Equipment

Greenhouses and nurseries need a wide variety of tools for land preparation, pruning, digging, and propagating. Pruning and digging tools are known carriers for spreading pathogens, since they regularly come into contact with soil and infected plant material. Cleaning tools and equipment after each use is an essential disease-management practice for greenhouses and nurseries. Sanitation begins with exclusion.

Exclusion

Preventing the entry of pathogens into the nursery is a highly effective strategy for disease control. Assigning specific tools and equipment for use exclusively in "clean" pathogen-free production areas and other tools for "dirty" production areas will help ensure that one area of your nursery has a much

The Importance of Good Sanitation

Proper attention to greenhouse and nursery sanitation is essential to reducing disease and pest outbreaks. In a 2019 survey of nursery growers on O'ahu, pest and disease management was listed as the number one bottleneck against increased productivity.

Diseases and pests can arrive through irrigation sources, soil and soilless media, plants, equipment, tools, growing containers, and, potentially, employees and visitors. Introduction of pathogens can also occur passively from areas surrounding the greenhouse and nursery, and plants on the perimeter of properties can be a constant source of pests and diseases.

Continual sanitation helps prevent outbreaks over the long term. Although it may seem like a waste of money and labor, the continuous positive effects and cost of pest control outweigh the recurring costs of maintenance sanitation.

This publication, part of a series covering the most important considerations in greenhouse and nursery sanitation, will focus on tools, equipment, workers, and visitors.

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higher likelihood of being pathogen-free, when combined with other management practices in this series.

Examples of “clean” production areas are stock plant holding areas or propagation areas with susceptible plants. These areas either have high-risk plants or are likely to be cleaner. “Dirty” areas can include sections of the nursery that are known to have disease problems, or the retail space. These areas are either known to have disease issues or the plants are being held for moving out of the nursery/greenhouse. Such tools should be labeled based on their location/use. All tools should be dried, sanitized and stored in clean, dry storage areas away from the production environment and splashing water. Tools should not be left on benches or on the ground anywhere in the production area. This routine will reduce the possibility of exposure to pathogens and damage due to rust.

Decontaminating Tools

Damaged tools and equipment can increase the likelihood of spreading disease. Nicks, scratches, and ridges create small pockets that harbor microorganisms and provide protection for pathogens during sanitation efforts, which can increase the survival rates of pathogens on tool surfaces.

Tools and equipment need to be free of debris and plant “sap” before disinfecting. Any debris still on the tools will reduce the efficacy of any decontamination method. Soap and water are one of the most common methods for cleaning tools. For heavily soiled tools, cleaning with high-pressure water or soaking the tools for a period of time is needed to remove caked-on soil or debris. Hot water is useful for breaking down plant exudates. For hard-to-remove sap, paint thinner can be used. These cleaning techniques are common for tools used on plants that produce latex, the white milky sap.

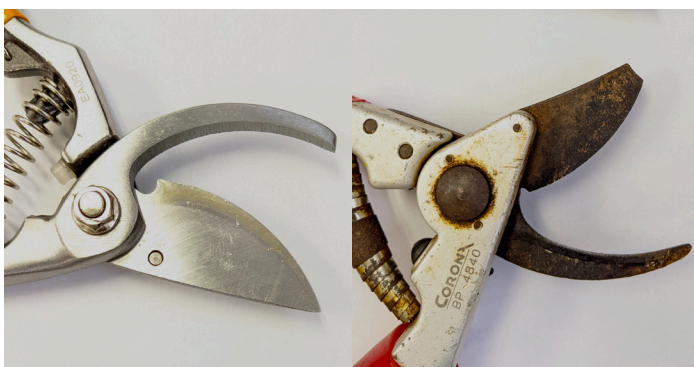


Figure 1. Clean tools, with less damage and debris, can harbor less pathogens. Ash from burning, dried plant sap and tissue, and any imperfections in the tools caused by damage, can be factors in the harboring of pathogens, thus hindering the efficacy of disinfectants.

Physical Control

Heating is one method that can be used on tools and equipment. This can be achieved using flame, solarization, or steam in the nursery setting.

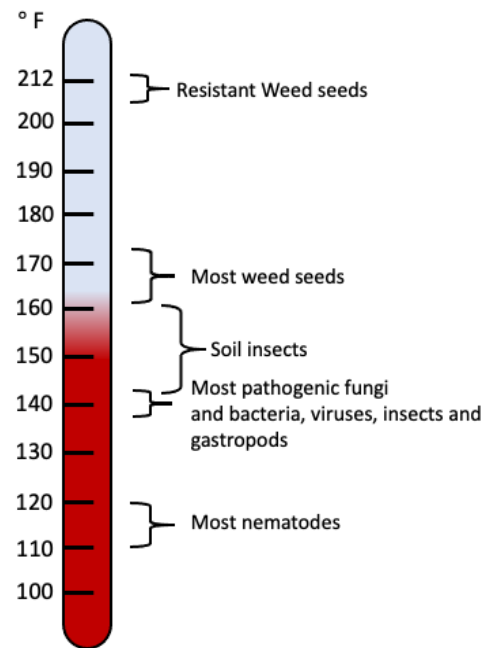


Figure 2. Generalizing the temperatures required to kill common plant pathogens, pests, and weeds. Heat treatment can be used to kill unwanted pathogens on tools.

Flame sterilization is a proven method of controlling pathogens on metal pruning equipment. The length of time that tools are exposed to the flame will determine how many pathogens get killed. Longer exposure means a higher likelihood of killing more pathogens. Flaming for 10 seconds can reduce pathogenic fungi by 95%, while 40 seconds can reduce it by 100% (Downer et al., 2009).

Debris should be removed from pruning equipment before flaming. Ash generated from burning debris during flaming can harbor microorganisms. The microorganisms retained within or behind the ash can survive further sanitation efforts.

Steam is an option for sterilization but is underutilized, mainly due to lack of equipment or a high equipment price. Steam-generating equipment that is useful for sterilizing tools and equipment is usually sold for weed control. They could be used directly or retrofitted with spray nozzles or hoods to better fit sterilization needs. Machines that have steam wands are useful for larger equipment, such as carts and machinery. Utilizing boiling water is a cheaper option if access to steaming equipment is not available.



Chemical Control

The use of chemicals is a common method for sterilizing tools and equipment because it is cheap and efficient. Always rinse and clean surfaces of soil and organic matter before applying disinfectants. These can reduce the efficacy of the disinfectants and provide hiding places for pathogens. Disinfectants should be applied only to tools and equipment and are generally not recommended to sterilize plant surfaces after damaging them with a tool, i.e. pruning wounds.

Green-shield® II, Physan 20™, and Kleengrow™ are three products available in Hawai'i that are labelled for sterilizing tools and equipment. They are almost identical to each other because all contain quaternary ammonium compounds as the active ingredients. They can be used as a dipping solution for small hand tools or applied over hard surfaces of large equipment. A 10-minute contact time is recommended. All three are labeled for use in nurseries and greenhouses and have recommended applications for disinfecting tools and equipment, and for the control of greenhouse and nursery algae.

Zerotol® 2.0, Oxidate® 2.0, and Sanidate® 5.0 are another family of products with hydrogen peroxide and peroxyacetic acid as the active ingredients. They can be used to sterilize tools and equipment, and as a soil sterilant. All three are labeled for use in nurseries and greenhouses, and have recommended application rates for tools and equipment. All three are labeled for control of greenhouse and nursery algae.

Virkon™ S is another disinfectant for use in horticultural settings but is not labeled for controlling plant pathogens. It does have labeled use in greenhouses and nurseries.

Household bleach (sodium hypochlorite) is one of the most common chemicals proven to control bacteria (Teviotdale et al., 1991), fungi (Copes, 2004), and viruses (Singh et al., 1989) in crops. It is a cheap and widely available disinfectant. However, a major complication with bleach is its corrosiveness to metals, which can damage metal tools and equipment and cause rusting. To avoid this issue, metal tools should be washed and coated with oil after bleach treatments.

Table 1. Common disinfectants used to sanitize tools, equipment, and surfaces in greenhouses and nurseries. Some disinfectants listed are not labeled for use in greenhouses or nurseries.

Product	Active Ingredient	Recommended Concentration	Labeled for use on horticulture tools?
Green-Shield® II	Ammonium chloride	1.5 fl. oz. per 5 gal for 10 minutes	yes
Physan 20™	Ammonium chloride	1 tablespoon per 1 gal for 10 minutes	yes
KleenGrow™	Ammonium chloride	0.5 fl. oz. per 1 gal for 10 minutes	yes
Zerotol® 2.0	Hydrogen peroxide Peroxyacetic acid	1.25-2.5 fl. oz. per 1 gal for 10 minutes	yes
Oxidate® 2.0	Hydrogen peroxide Peroxyacetic acid	1.25-2.5 fl. oz. per 1 gal for 10 minutes	yes
Sanidate® 5.0	Hydrogen peroxide Peroxyacetic acid	0.5-2.2 fl. oz. per 1 gal for 10 minutes	yes
Virkon™ S	Potassium peroxymonosulfate sodium chloride	0.65-2.7 fl. oz. per 1 gal for 10 minutes	yes
Alcohol	Ethanol or isopropyl alcohol	70% alcohol for 10 minutes	no
Chlorine Bleach	Sodium hypochlorite	10% bleach solution or 10-30 minutes	no
Lysol	Benzalkonium chloride	1-1.25 fl. Oz. per gal for 10 minutes	no

Bleach is also damaging to clothing, humans, and plants. Tools should be dipped in bleach for a minimum of 60 seconds and up to 30 minutes, depending on the pathogen and the desired degree of disinfection. Some pathogens, such as viruses and certain fungi, will require more time to disinfect. A general suggestion is to dip tools in bleach for two minutes. Bleach should be mixed at a rate of 10%. This means 1 part concentrated bleach should be diluted with 9 parts of water. To make a gallon of bleach solution, add 2 cups of bleach to a 1-gallon container and then add water until the gallon fill line is reached. Bleach loses efficacy by 50% after 2 hours, so it should be replaced every 2 hours.

Isopropyl alcohol or ethanol is another common chemical disinfectant. This product is generally less effective in disinfecting compared to bleach, but will not corrode metal equipment or ruin clothing. Concentrations of 70% - 91% can be used to disinfect tools and equipment and do not need to be diluted. Rubbing alcohol does not need to be replaced every two hours, as is the case with bleach. Contact time varies between 60 seconds and 30 minutes, depending on the pathogen, with a general recommendation of 10-15 minutes soaking time for tools. Alcohol at a concentration of 70% will be less effective at disinfecting tools than 91% alcohol, and will take longer to achieve disinfection.

For more information about products approved by the federal government and state of Hawai'i for human and horticultural use, visit NPIRS Public (purdue.edu).

Remember, the label is the law. Always read and closely follow the product label for specific use.

Vehicles

Cars and trucks owned by the company, workers, customers and delivery vendors are an often-overlooked source of contamination. These vehicles can carry pathogens and weed seeds, particularly in soil stuck on the tires and undercarriage. To limit the spread of pathogens and weeds, only nursery vehicles should be allowed in the growing areas of the property. The layout of the property should be designed to exclude outside vehicle traffic through any growing areas or roads that nursery vehicles will also traverse. Loading and unloading areas should be defined only for vehicles dropping off and picking up goods. Customer and worker vehicles should only enter specific parking areas. Preventing the spread of disease by limiting vehicle access is a cheap and passive method of prevention. Vehicles can be disinfected using steam or chemical disinfection, as described above. Vehicles should be thoroughly washed and disinfected before entering the growing areas of the property.

Roads and paths in the nursery should be elevated and dry, with as little water pooling as possible. Puddles can harbor diseases and disease vectors, such as fungus gnats.

Vehicles can splash water from roads on plants and soil. Reducing low points and areas with puddles will reduce these incidents, along with limiting vehicle traffic in growing areas to only vehicles used on property.

Worker & Visitor Sanitation

A major source of greenhouse and nursery contamination comes from people entering the site.

People spread plant diseases, insects, and weed seeds through dirty clothing, shoes, and hands. Workers and visitors who forget to wash their hands after touching diseased plants may transfer bacterial, fungal, or viral pathogens to healthy plants. Soil adhering to worker's or visitor's shoes may spread soilborne pathogens. Insect pests, such as thrips, aphids, and mites, can hitchhike on hands and clothing. Invasive plant seeds and microscopic airborne fungal spores could stick to clothing. Each time a worker or visitor steps inside the plant nursery, he/she may accidentally introduce these undesirable pests and pathogens. For this reason, it is critical to maintain and practice good hygiene when working with plants.

This publication discusses activities and decontamination protocols for workers and visitors to practice proper sanitation in crop areas. Providing education and implementing sanitation practices is necessary so that people understand how they could accidentally introduce or spread plant diseases and pests in the greenhouse or nursery.

Worker Training Activities to Reduce Contamination

Providing training to new and existing employees can help prevent the introduction and spread of plant disease, weeds, and insects. Establishing the following ideas will help workers practice good hygiene to keep plants healthy and clean.

I. Educate employees about the plant disease cycle to help them understand how and why plant diseases develop.

Plant disease occurs when a pathogen, such as fungus, bacterium, virus, or nematode affects a susceptible host plant during favorable environmental conditions, often referred to as the "disease triangle" (Hosack & Miller, 2017). Humans cannot control outdoor weather, but we can take steps to control pathogens from spreading. By removing pathogens, a component of the disease triangle, we can stop the disease from developing. For more information about the disease triangle and disease development, refer to Agrios (2005).

II. Understand how humans may contribute to the spread of diseases.

Soil-borne fungal pathogens, such as *Pythium*, remain viable in the soil (Agrios, 2005). Contaminated soil can

stick to boots and clothing, and can be transported and spread by walking around. Root-rot diseases, such as *Phytophthora* sp., actively swim in soil water and can be transferred through dirty boots (Sims et al, 2016).

Some bacterial plant pathogens produce sticky ooze or sap containing millions of bacterial cells that easily spread by touching the ooze and splashing onto clothes, hands, and other plants during watering (Hosack & Miller 2017).

Viral diseases can be transmitted to healthy plants through dirty or contaminated hands, or through insect vectors. For instance, tobacco mosaic virus (TMV) is transmitted to plants simply by touching susceptible plants after smoking nicotine products that contain TMV, or touching contaminated tools (Scholthof, 2004). Hemipteran insects, such as scales, mealybugs, aphids, and leafhoppers, can transmit viral diseases through feeding (Agrios, 2005).

III. Learn to recognize plant disease symptoms and insect damage.

Plant disease symptoms include: rot, rapid seedling death, wilting, leaf spots, stunting, oozing or bleeding, cankers, galls or lumps, mottling, discoloration, and streaking. Symptoms of insect feeding damage include: trailing, leaf spots, holes in leaves, stippling, yellowing or chlorotic spots, browning, bronzing or necrotic tissues, presence of sticky honeydew, and silk-webs. Most insects move on their own, but some can hitchhike on human clothing, shoes, or hands. For this reason, it's important to follow items outlined in sections IV and V to sanitize clothing, shoes, and hands of workers and visitors to prevent the spread of pathogens and insects throughout the greenhouse. Encourage workers to observe, record, and monitor plants to avoid further spread of pathogens and insect pests.

IV. General guidelines

Install decontamination stations outside the greenhouse for clothes, shoes, and hands. Decontamination stations should include: brushes, water hose or power washer, soap, basin, foot bath, hand spray bottle, isopropyl alcohol and/or ethanol, removable or disposable clothing, and foot covers. Install handwashing stations inside and outside of the greenhouse. Equip handwashing stations with clean water, hand soap, paper towel and/or clean clothes, a garbage can, hand sanitizer, and disposable gloves.

Establish quarantine zones, and place diseased or insect infested plants in areas far away from healthy plant material. For instance, create quarantine zones outside of the plant nursery, or sectioned/contained areas within the greenhouse. If introducing new plant material into



Figure 3. Decontamination station containing footbath, brushes, and hand-spray bottle with 70% isopropyl alcohol to clean and sanitize footwear and clothes prior to greenhouse entry.

the greenhouse, use these quarantine zones to observe and monitor plants before moving them into production areas and/or exposing them to healthy plants.

When working with diseased or sensitive plants, such as cuttings or root stock, encourage employees to wash their hands and change into clean clothes and shoes. Another option is to use disposable foot covers and clean gloves (fig. 4). Encourage employees to work from clean to dirty production areas. After working with diseased plants, remove dirty clothing or coveralls, clean and sanitize footwear and gloves. Microscopic bacterial cells and fungal spores can remain viable on clothing and boots for multiple days.

Stock the greenhouse/nursery with sanitation supplies. Consider posting plant disease and insect identification charts inside the greenhouse. Place notebooks and pencils for record-keeping to help all employees monitor and contain issues inside the greenhouse or plant nursery.

V. Establish and practice decontamination protocols for footwear, hands, and clothing outlined in decontamination protocols below.

Decontamination Protocols

I. Footwear

Upon entry and exit, always decontaminate and sanitize footwear.

Materials: shoes, scrub brush, footbath or container, hand spray bottle, clean water, soap, and 70-90% isopropyl alcohol or ethanol

Procedure: remove all soil, seeds, and plant debris from shoes with scrub brush, rinse, or soak boots with water and soap, dry boots with paper towel/cloth or air-dry in the sun or place on a shoe hanger, sanitize boots with undiluted 70-90% isopropyl alcohol or ethanol.

Footbaths are effective when cleaning dirty, soiled boots. To sanitize boots, use a second foot bath or spray bottle filled with isopropyl alcohol, ethanol, or other disinfectants listed above. A hand-held spray bottle can be used to apply sanitizer, which may conserve more product compared to footbath. Keep clean boots or disposable shoe covers available for workers to use.

Product	Uses	Comments
Ethanol 70-90%	Sanitizes footwear and clothing	Flammable, quickly evaporates
Isopropyl alcohol 70-90%	Sanitizes footwear and clothing	Flammable, quickly evaporates
Soap	Aides in the mechanical removal of contaminants	Dilute with water, rinse after washing
Multi-purpose cleaning solution	Aides in the mechanical removal of contaminants	Read and follow the product label

Warning: isopropyl alcohol or ethanol is flammable and readily evaporates. Use and store isopropyl alcohol or ethanol in a closed container in areas away from flame or fire. Smoking should be prohibited at decontamination stations.

II. Hands

Thoroughly wash hands after using the bathroom, eating, smoking, and touching diseased or infected plants.

Materials needed: clean water, hand soap, paper towel and/or clean cloth, garbage bin, gloves.

Procedure: wash hands with soap and clean water, remove soil from fingernails, rub hands together for 20 seconds, dry hands with paper towel or clean cloth, dispose of paper towel. Frequently wash hands and use hand sanitizer.

If working with chemicals, disposable gloves are required. Wearing waterproof disposable gloves (i.e., nitrile, vinyl, latex) when working with diseased plants or sensitive plant material is highly recommended. Dispose of gloves after touching diseased or contaminated plants or soil. Leather or cloth gloves are not recommended because contaminated soil and debris may adhere to these materials. Only use leather or cloth gloves if thoroughly cleaned and sanitized, and change them each time a worker touches a diseased plant. If water and soap are not available, use a hand sanitizer and encourage the use of gloves.

III. Clothing

Upon entry into the greenhouse or crop areas, inspect and remove dirty clothes that were exposed to outdoor areas, field conditions, and landscapes.

Materials: extra clothing, disposable clothing (i.e. Tyvek suit), coveralls, clothing brush

Procedure: inspect clothing for weed seeds, insects, and soil, then remove soiled clothes and place in a hamper or closed lid system outside of crop areas. Change into clean clothes free of soil and plant debris or use removable covering, such as disposable Tyvek suits (fig. 5), aprons, or



Figure 4. Mason Russo, PhD student at the University of Hawai‘i at Mānoa, practicing good hygiene by using disposable gloves and by wearing a Tyvek suit when handling insect infested plants and pesticides.



coveralls. Encourage employees to keep a spare change of clothing with them at all times.

Establishing Visitor Protocol and Education

Depending on the business model, some nurseries encourage visitors, while others remain closed to the public or are open by appointment only. Consider restricting entry or supervising visitors in sensitive areas of the nursery. Train employees to inspect visitors' clothing and shoes for weed seeds, insects, and soil. Encourage visitors to wash their hands with soap and water, use a hand brush to remove seeds and soil from shoes and clothing. Ask visitors where

Table 3. Greenhouse and Plant Nursery Sanitation Supplies

Product	Uses	Comments
Nitrile disposable gloves	Working with chemicals or contaminated plants	Hypoallergenic
Vinyl disposable gloves	Working with chemicals or contaminated plants	Hypoallergenic
Latex disposable gloves	Working with chemicals or contaminated plants	May cause allergic reactions
Disposable protective clothing	Use when working with chemicals	Dispose after contamination

they commuted from and if they recently traveled to a place that harbors detrimental diseases, noxious plants, or pests.

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Disclaimer

The pesticides mentioned in this publication are provided as suggestions and should not be considered as recommendations. **The pesticide label is the law.** Read it before purchasing a pesticide to ensure it is registered for your intended use. Carefully read the label entirely before use and follow its instructions.

Chemical names and trade names are included as a convenience to the reader. Their use in this publication does not imply endorsement, nor discrimination against similar products or services not mentioned. Individuals who use chemicals are responsible for ensuring that the intended use complies with current regulations and conforms to the product label. Be sure to obtain current information about usage and examine a current product label before applying any chemical. For assistance, contact your state pesticide regulating authority.

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