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CNPS Best Management Practices (BMPs) for Producing Clean Nursery Stock

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Introduction

This document contains best management practices (BMPs) recommended for CNPS Chapters that hold Chapter plant sales. This document is one in a series prepared by CNPS to implement its policy on *Preventing Infection and Spread of Harmful Pathogens via Native Plant Nursery and Plant Sale Stock*, which was adopted by the CNPS Chapter Council on 6 December 2015. Adoption of this policy was triggered by the widespread detection of multiple soilborne *Phytophthora* species in native plant nursery stock grown for habitat restoration projects and other uses, including Chapter plant sales. These *Phytophthora* species are serious invasive pathogens that threaten California native plants in natural stands, restored habitats, and horticultural landscapes. CNPS supports the use of these BMPs by nurseries that provide plants for Chapter plant sales to minimize these threats.

Start clean, keep it clean

Root rots caused by soilborne *Phytophthora* species have been recognized as important disease problems in nurseries for many decades. These plant pathogens can stunt or kill plants in the nursery, although infected plants may not show symptoms until nearly all roots are dead. More importantly, infected nursery plants can deliver pathogens into the landscape. These introduced *Phytophthora* species can debilitate or kill the planted material, and spread from the planting site to attack and kill adjacent vegetation. The planting site can become permanently infested, causing long-term problems in the landscape, limiting the type of plants that can be grown, and serving as a source of spread to other areas.

A thorough, integrated systems approach to clean plant production is needed to produce plants that are free of *Phytophthora*. The concepts behind a clean production system can be summarized in two points

- **Start clean** by use of clean starting components, including plant propagules, containers, potting media, and water.
- **Stay clean** by using clean production practices and organizing your nursery in a way that separates potentially contaminated materials from your clean plants.

The goal of a clean production system is to prevent the introduction of *Phytophthora* into nursery stock rather than attempting to suppress it after plants are already infected. If there is no *Phytophthora*, there will be no *Phytophthora* diseases.

Systems approach to producing clean nursery stock

The most effective way to produce *Phytophthora*-free nursery stock is following an integrated systems approach to excluding these pathogens through the entire plant production cycle. A systems approach to clean plant production takes constraints and properties of the nursery into account. Various approaches may be used to meet clean production standards, but in the end, the complete system needs to address all of the risk factors (aka critical control points) that may allow *Phytophthora* or other serious pathogens or plant pests to infest nursery plants. The BMPs that follow are a list of specific practices that should be

followed to implement a systems approach. However, they cannot cover every practice or contingency that may arise in every nursery.

What is a systems approach?

Many features of plant nurseries put them at high risk for pest and disease issues, especially *Phytophthora* root diseases and foliar blights (see PLANT NURSERY CONDITIONS FAVOR *PHYTOPHTHORA* ROOT ROTS). The risk of these diseases is not related to a single factor; it arises from a number of interrelated factors that confer risk. For this reason, it is not possible to identify a few simple practices that will mitigate these risks. It is necessary to consider the entire plant production cycle in the nursery from beginning to end and examine all of the elements that pose a risk of introducing pathogens into the system and allowing them to propagate.

This concept is not new. Baker (1957) clearly stated that production of healthy nursery stock requires an integrated approach. He also noted that it was necessary to adopt the entire clean production system to achieve the goal of producing healthy plants. As an analogy, if you have a bicycle tire with many holes, it will not hold air if you decide to only patch some of them. In the same way, if you allow *Phytophthora* to contaminate your plant material at any point in the production cycle, you cannot end up with clean plants even if you follow some good production practices.

A widely-used systems approach for preventing contamination of products is the Hazard Analysis of Critical Control Points (HACCP) system. Parke and Grunwald (2012) present a discussion of the development of HACCP systems and discuss the application of this approach to clean nursery production. In short, a HACCP system involves conducting a hazard analysis to identify Critical Control Points, i.e., points in the production process where contamination can occur. Measures and limits are developed to address these points, and ongoing monitoring and record keeping are used to verify that the controls are adequate and working. To return to the bicycle tire analogy, the HAACP system determines where all the holes are, specifies a patch for each one, and checks to see that all of the holes are properly patched and that the tire holds air.

A structured system such as this becomes more important as the size and complexity of a production system increases and if many different people are involved in parts of the system. Smaller, simpler nursery operations, can also benefit by using a HACCP system, but may be able to take a somewhat less formal approach. To successfully implement a clean nursery production system, it is most important that all nursery personnel understand how contamination can be introduced into the nursery, and how to prevent that from occurring. Much of this can be accomplished by consistently applying several basic rules of thumb, as described below.

Simplified model for clean nursery production

Basic concepts:

A. **Contamination by microorganisms like *Phytophthora* cannot be seen.** For day to day operations, assume that *Phytophthora* can be introduced anytime that a clean surface or material comes in contact with something that is contaminated.

B. **Clean vs. Contaminated.** For the purposes of producing *Phytophthora*-free nursery stock, the system can be divided up as follows:

Clean	**Contaminated**
no *Phytophthora* present	Could have *Phytophthora* present; will be treated as if it is present
Includes: 1. Materials that are innately free of contamination due to manufacturing conditions (e.g., new, uncontaminated plastic or paper, perlite, vemiculite). 2. Materials treated in a way that effectively eliminates *Phytophthora* (e.g., lethal heat or disinfectants. Note: fungicides do not eliminate *Phytophthora*)	Includes: Almost everything else, but primarily anything that has the potential to have been in contact with soil, untreated water, or plant material (e.g., non-pasteurized sand, compost, forest product and peat moss used in container mixes).

Basic rules of thumb

1. **Clean + clean= clean.** If all inputs (plant materials, container mix, pots, water) are clean and there is no contamination during production, the plants will remain clean.

2. **Clean + contaminated = contaminated.** Clean items should never be allowed to come into contact with contaminated materials.

3. **Contaminated plants stay contaminated.** Once contaminated, live nursery plants cannot be made clean again.

4. **If unsure, assume it's contaminated.** Any tool, surface (including benches, hands, and gloves), or input (plant materials, container mix, pots, water) should be considered as contaminated unless you know or have documentation it was sanitized or treated to kill *Phytophthora* and was not subsequently contaminated.

5. **The ground is always contaminated.** The ground surface and any water in contact with it (including water splashed from it) should always be considered to be contaminated.

6. **Contamination spreads with water splash.** Clean plants or other materials that receive water splash from contaminated plants or surfaces will become contaminated. Water splash from rainfall-sized droplets in still air can reach a height of about 0.6 m (2 ft) and can spread laterally up to about 1.5 m (5 ft). Splash dispersal distances can be greater under windy conditions or with larger drops (such as runoff from roofs, etc.) or if generated by water under pressure (e.g., hose nozzle) or mechanical forces (e.g., vehicle splashing through a puddle).

All of the clean nursery production best management practices (BMPs) have their foundation in these basic concepts and rules. The BMPs are simply applications of these rules to specific situations encountered in the plant production process. Because it is not possible to anticipate every possible situation in every nursery, lists of BMPs can always have gaps. However, if all nursery workers internalize and consistently apply the basic concepts and rules of thumb above, they will be able to do the right thing in terms of working practices without constantly referring to specific BMPs. To use the bicycle tire analogy one more time, this is the equivalent of filling the tube with a sealant: all holes are filled and new ones are filled as they develop. You don't necessarily need a detailed list of every possible hole if you intuitively work in ways that keep the holes filled.

These rules of thumb apply to soilborne *Phytophthora* species as well as a number of other soilborne pathogens. Some *Phytophthora* species also cause foliar infections. These include species such as *P. ramorum*, the sudden oak death pathogen, as well as some of the soilborne species that cause root rots. For *P. ramorum* and some other similar species that are primarily splash-dispersed foliar pathogens, airborne spores can be introduced into the nursery from infected native or planted hosts. Most of the risk is associated with hosts that are within the range of wind-blown water splash from leaf surfaces, so the risk is low at distances of more than about 10 m (30 ft) or more. Although many pest and disease issues will be minimized by following clean production practices, pathogens and insects that are capable of being dispersed via air over longer distances will not necessarily be eliminated by following these practices.

Additional resources

Griesbach et al (2012) provides a good discussion of using a systems approach. However, this manual is generally directed toward larger commercial nurseries and includes standards that will minimize but not eliminate *Phytophthora* in the nursery. Kenneth Baker's classic publication "The U.C. System for Producing Healthy Container-Grown Plants" (https://archive.org/details/ucsystemforprodu23bake) is still an excellent reference for a wide variety of clean propagation practices. The discussions about the use of chemicals are out of date, but the discussion of cultural practices and sanitation are timeless.

Baker, K.F. Editor. 1957. The U.C. System for Producing Healthy Container Grown Plants, Manual 23. University of California, Division of Agricultural Sciences, Agricultural Experiment Station Extension Service.

Griesbach, J.A.; Parke, J.L.; Chastagner, G.A.; Grünwald, N.J.; Aguirre, J. 2012. Safe procurement and production manual: a systems approach for the production of healthy nursery stock. Wilsonville, OR: Oregon Association of Nurseries. 98 p.

Parke, J.L.; Grünwald, N.J. 2012. A systems approach for management of pests and pathogens of nursery crops. Plant Disease 96:1236-1244.

Best Management Practices

Contents

1. Definitions 5
2. Clean planting materials 8
3. Clean containers 10
4. Clean potting media 11
5. Clean water 12
6. Clean production practices 13
   6.1. Workers and visitors 14
   6.2. Nursery design, layout, and work flow 16
   6.3. Benches and growing areas 18
   6.4. Tools, surfaces, and the nursery environment 19
   6.5. Other cultural inputs 21
   6.6. Inspection and testing 22
7. Record keeping 24
8. Taking plants to off-site sales 25

1. Definitions

For the purposes of this document, the following definitions apply.

Batch — a group of plants with a common risk profile with respect to potential for contamination in the propagation process. Generally, a group of plants of a single species with a common source of propagative material that is started at the same time using the same potting media (composition, treatment, handling). Plants within the batch are normally handled in the same way after potting and may or may not be spatially grouped (see block). **Related batches** are those that share one or more common risk factors (e.g., same potting media batch but different propagative material or date of planting). If a *Phytophthora* detection is made within a given plant batch, that batch and related batches are considered potentially contaminated until the source of contamination can be determined via testing and records.

Block — a spatially grouped array of plants on a bench, normally from a given batch. A block of plants normally has a common risk profile with respect to potential for contamination associated with nursery practices after potting (e.g., accidental introduction via contaminated hands or tools) related to potential for pot-to-pot splash. If a *Phytophthora* detection is made within a given plant block, that block and adjoining blocks are considered potentially contaminated until proven otherwise via testing and records.

Clean — sanitized, heat-treated, or new (e.g., plastic pots), and maintained in a way to prevent subsequent contamination.

Clean production area — Entire nursery production area or a fenced, posted, separated area maintained to exclude contaminated materials to the best degree possible.

Clean production system — an integrated system for producing plants that are free of soilborne *Phytophthora* species. Plants produced following these specifications are also likely to be free of most significant soilborne pathogens, but will not necessarily be free of all pathogens and pests.

Contaminated or potentially contaminated — any surface or material that is not freshly sanitized, heat-treated or otherwise clean. The ground, soil and potting media that has not been heat treated, used pots, plants not produced following these BMPs (including all plants from other nurseries or in natural or planted landscapes), and anything that has been in contact with these should be considered as potentially contaminated.

Cull — as a verb, to pick out for the purpose of discarding (e.g., plants showing disease symptoms are culled). As a noun, cull refers to the items (e.g., diseased plants) that have been selected for discard.

Disinfectant — materials such as bleach (sodium hypochlorite solutions), alcohol, quaternary ammonium compounds, and peroxides that can directly kill exposed propagules of *Phytophthora* or other plant pathogens when used properly. Most disinfectants can also kill a wide variety of bacteria and deactivate many viruses. Note that most materials normally referred to as fungicides are applied to plants to suppress disease but do not actually kill the pathogens (see HOW USING FUNGICIDES IN NURSERIES CAN INCREASE THE RISK OF MOVING *PHYTOPHTHORA* TO PLANTING SITES) .

Heat-treated — in regards to potting medium, containers, etc., free of plant pathogens through exposure to heat at a temperature and time duration that will that kill plant pathogens, and subsequently handled and maintained in a manner to prevent contamination (see PHYTOSANITARY PROCEDURES FOR CNPS BMPS FOR PRODUCING CLEAN NURSERY STOCK).

Infected — a plant that has a pathogen that has grown into its tissues. Infections normally involve internal colonization of plant tissues and are not eliminated via surface treatments such as disinfectant dips. Only plants or plant parts are referred to as infected (see also infested).

Infested — containing or superficially contaminated with propagules of a pathogen. Soil, potting media, tools, and surfaces may be infested with spores of pathogens (see also infected).

Phytosanitary — free of plant pathogens; as an adjective, used to describe techniques or practices that prevent materials from being infected or infested with plant pathogens (e.g., phytosanitary measures).

Potting media — substrate used for germinating, rooting, or growing plants in containers. Typically a mixture of organic and inorganic materials.

Propagule — living portions of a plant, fungus, oomycete, etc. that can serve to reproduce that organism. For plants, propagules include seeds, cuttings, divisions, bulbs, corms, tubers, etc. For fungi or oomycetes (including *Phytophthora*), these include both vegetative filaments (mycelium) as well as various spores and resistant structures.

Sanitized — cleaned to remove debris and soil particles and subsequently treated with a disinfecting agent such as sodium hypochlorite (chlorine bleach), quaternary ammonium compounds, alcohol, or heat in a manner that destroys any residual plant pathogen propagules.

2. Clean planting materials

Objective: start with propagative material that is free from infection or external contamination by *Phytophthora* species as well as other possible pathogens.

What you need to know: *Phytophthora* propagules can move in infested soil and water. Water splash can disperse spores at least up to a height of about 0.6 m (2 ft) and a horizontal distance of 1.5 m (5 ft) (see Basic Rule of Thumb 6 above). Spores splashed from the soil surface can initiate above-ground infections of flowers, leaves, and stems. Seeds lying on infested soil can become infested or infected, especially under moist conditions. Infested or infected propagules can introduce *Phytophthora* into the nursery, where it can develop and spread. Tools and boots contaminated with soil containing *Phytophthora* spores can introduce *Phytophthora* species from outside areas into the nursery, or conversely into seed or collecting areas outside the nursery.

Best practices:

2.1. Don't collect plant materials for propagation in areas known or likely to be infested with *Phytophthora*. Only a small percentage of the *Phytophthora*-infested areas that exist have been documented. As a general rule, assume that nurseries and cultivated landscapes (yards, gardens, parks, botanical gardens, arboreta, etc.) have the potential to be infested. Some natural areas, including portions of regional or state parks, open spaces, ecological reserves, and private lands are also infested.

2.2. Collect seeds, cuttings, or other propagules only from plants and fruit that appear healthy. Do not collect or store seeds or other propagules with apparent disease symptoms such as decay, atypical discoloration, or fungal fruiting bodies,.

2.3. Don't collect seed from the ground. Collect seeds and cuttings as high above the ground as possible, preferably at least 3 ft above the soil surface.

2.4. Don't collect during wet or muddy conditions.

2.5. Collect propagules with clean hands/gloves and equipment (pruning shears, etc.) and place them in new bags/envelopes and new or clean containers. Sanitize gloves, hands, and tools immediately if they come in contact with soil. Sanitize cutting tools frequently.

2.4. Do your part to avoid introducing *Phytophthora* into seed collection areas. Make sure your equipment, vehicle, and footwear are clean. Clean and sanitize your footwear and tools between locations.

2.5. Conduct all processing of seeds or cuttings in a clean work area with clean equipment and clean hands or gloves. Discard or sanitize any seed or propagule that is dropped on the ground or comes in contact with contaminated surfaces or materials.

2.6. Clean seed as soon as possible after collection to remove any debris before storage and stratification. Inspect stored seeds or other propagules regularly and discard materials that develop symptoms in storage.

2.7. Do not bring potentially infected or contaminated plant material into clean production areas of the nursery. Properly collected seed and tip cuttings (described above) will normally be free of *Phytophthora.*

2.8. Plant propagules that have been in contact with the soil (divisions, tubers, rhizomes, bulbs, etc.) have an elevated risk of being infected or contaminated with *Phytophthora* or other soilborne pathogens. Plant stock originating from such propagules should be segregated from planting material started from cleaner sources, such as seed or cuttings. See "Propagating from field-grown plants (link)" for a more complete discussion about the implications of using propagules from soil.

2.9. Plant propagules from the soil (divisions, tubers, rhizomes, bulbs, etc.) should be thoroughly cleaned to remove soil and inspected. Discard propagules that show evidence of decay. Surface contamination can be removed with treatments such as diluted bleach dips, but surface treatments will not eliminate internal infections. Internal infections can only be eliminated by heat treatments, but not all plant propagules will tolerate temperatures needed to kill *Phytophthora* infections (see PHYTOSANITARY PROCEDURES FOR CNPS BMPS FOR PRODUCING CLEAN NURSERY STOCK).

2.10. Assume nursery stock from others is infested and do not bring such material into clean production areas of the nursery. If a native plant nursery or other grower has had a well-documented and certifiable clean production system in place for the entire time that their current inventory has been in existence, the stock may be clean. Place such material in quarantine for at least 3-4 months for observation and testing. See EVALUATING BUY-IN MATERIAL FOR *PHYTOPHTHORA* for further details.

3. Clean containers

Objective: Use clean containers to eliminate these as a potential source of pathogens

What you need to know: Remnant soil in used pots can contain *Phytophthora* spores and introduce *Phytophthora* species into the nursery. Clean pots can become contaminated through improper storage and poor sanitation practices.

Best practices:

3.1. Use only new or cleaned and sanitized pots/flats/containers in the nursery.

3.2. Do not allow your clean containers (new or sanitized) to become contaminated.

- Store containers off the ground on clean racks or shelves out of reach of splashing water or in covered bins.
- Never place clean containers on the ground, in water, or on other potentially contaminated surfaces.

3.3. Assume that used pots and flats are contaminated. Don't store dirty containers in or near clean areas of the nursery and don't let them accumulate. Clean or dispose of them promptly. Keep used pots and flats in a bin or enclosed area outside of clean nursery area where the contamination can be contained and cleaned up.

3.4. Used pots/flats must be cleaned of old potting media and plant material and sanitized using heat or disinfectants (see PHYTOSANITARY PROCEDURES FOR CNPS BMPS FOR PRODUCING CLEAN NURSERY STOCK). The container cleaning area should not be in the clean area of the nursery (see "Nursery design, layout, and work flow" below).

3.5. Use the smallest size containers possible to minimize expenditures related to cleaning and sanitizing used containers.

3.6. Plant stakes, irrigation emitters and lines, descriptive signs, etc., that are placed on, over, or in pots should be new or sanitized.

3.7. Bins for holding heat-treated potting media should be sanitized before refilling.

4. Clean potting media

Objective: All potting media must be heat treated unless components are certifiably pathogen free and have been handled and stored in a manner that precludes contamination.

What you need to know: Because nurseries are so conducive to development of *Phytophthora* infections, low amounts of *Phytophthora* spores in potting media can lead to a high rate of contamination in the nursery. However, unless it is very highly contaminated, it is difficult to effectively test large volumes of soil to determine whether they are free of *Phytophthora*. Contamination can be introduced to potting mix through contaminated components (sand, peat, compost, forest products), contaminated water, use of contaminated containers, or contact with contaminated tools, equipment, and surfaces. Proper heat treatment eliminates *Phytophthora*, ensuring that you start with clean potting media.

Best practices:

4.1. Always use use heat-treated germination media and potting media. Moist heat is the most effective for killing Phytophthora. Heating specifications are discussed in Phytosanitary Procedures for CNPS BMPs for Producing Clean Nursery Stock under "2.4. Heat treatment of potting media".

4.2. Commercial vermiculite and perlite in sealed bags from the primary manufacturer or bagged potting media that has been heat-treated should be pathogen-free if it has been handled in a manner to prevent contamination.

4.3. Handle heat-treated potting media in a manner to prevent contamination. Store planting media in clean, covered bins. Stored heat-treated potting media should not come in contact with the ground or be exposed to water splash or runoff. Do not contaminate heat-treated potting soil by using nonsanitized tools, hands, gloves, or by walking on it.

4.4. Using the smallest size containers possible will reduce the amount of potting media that needs to be treated.

5. Clean water

Objective: use only uncontaminated, appropriately-treated water for irrigation.

What you need to know: Surface waters, especially recycled nursery runoff, are known sources of *Phytophthora* contamination. Some species of *Phytophthora* not only survive, but actively cycle in streams and ponds.

Best practices:

5.1. Use known clean water sources. Most CNPS nurseries have access to clean sources of water. If your irrigation water comes from treated municipal water supplies (including tertiary-treated recycled water) or properly maintained wells, the water will not contain *Phytophthora* spores. .

5.2. Do not use untreated irrigation runoff or water from surface streams or ponds. Water from these sources can be contaminated and can spread that contamination through the nursery. Contaminated water can be disinfested by appropriate ultrafiltration or treatment with chemicals or ultraviolet light. These treatment methods are relatively expensive and not likely to be practical for most CNPS nurseries.

5.3. Don't let your water become contaminated. Make sure that your plumbing system is intact and properly protected with backflow prevention devices so that contaminants from the soil or runoff water can't enter the system. As discussed under clean production practices, make sure that all hose ends, nozzles, emitters, and other irrigation equipment do not come in contact with the ground and are sanitized before use on clean benches and plants. Re-sanitize drip irrigation equipment whenever it is moved to a different set of plants.

6. Clean production practices

Objective: prevent contamination of initially clean plant materials by consistent, comprehensive phytosanitary working practices.

What you need to know: There are over 120 described species of *Phytophthora*, each with its own host range and temperature preferences. *Phytophthora* species are microscopic organisms invisible to the naked eye, so it is very easy to unwittingly move them in the nursery. *Phytophthora* infested soil looks the same as uninfested soil, and you can't tell whether surfaces, tools and hands are clean or contaminated just by looking at them. Plants that appear healthy may be infected and can spread contamination to adjacent plants, surfaces, tools, and gloves. *Phytophthora* spores can be splashed in water droplets spores at least to a height of about (0.6 m) 2 ft and horizontal distance of 1.5 m (5 ft) (see Rule of Thumb 6 above).

With clean inputs of *Phytophthora*-free plant materials, potting media, containers, and water, plants will remain clean unless they are subsequently contaminated, so clean production practices are crucial. Even if plant batches are managed to be as clean as possible, the longer that plants remain in the nursery, the more chances they have to become inadvertently contaminated. Every batch of plants is both protected from contamination and considered a potential source of contamination to other batches. This is why benches, irrigation lines, containers, etc., are sanitized after use even though they have been sanitized at the start of production. This is also another reason to minimize the amount of time that plants remain in the nursery by producing and selling the stock in the smallest size that is feasible.

If you are converting an existing nursery to clean production practices, there will initially be many potential sources of contamination within the nursery. However, if you have been following clean production practices for an extended period, the plant stock being produced should be free of *Phytophthora*, which will reduce the risk of contamination from sources in the nursery. Although the ground within the nursery should always be considered contaminated (Basic Rule of Thumb 5 above), in a clean production system, most potential sources of contamination originate outside of the nursery.

6.1. Workers and visitors

Objective: ensure that all personnel that work in or visit the nursery consistently follow phytosanitary practices

What you need to know: Everyone who works in the nursery needs to understand how *Phytophthora* spreads and how to avoid spreading it. For many, this will require substantial changes in thinking about how they go about tasks in the nursery. Personal protective equipment may need to be worn for some sanitizing procedures. Personal protective equipment that is reused needs to be cleaned and/or sanitized as appropriate. Visitors will be less informed about phytosanitary practices, so you need to ensure that they follow proper protocols or exclude them from clean areas of the nursery. This practice is applied in any critically clean situation in many industries.

Best practices:

6.1.1. Nursery workers should be trained in approved phytosanitary procedures and follow the procedures at all times. Make sure nursery workers have access to resources that discuss BMPs and clean nursery practices so they understand how *Phytophthora* spreads and the reasons for clean working practices. Encourage workers to ask questions if they are unclear about procedures or their rationale.

6.1.2. Clothing worn in clean areas of the nursery should be free of contamination. Don't enter clean areas wearing clothes that may have soil from your yard, other landscaped areas, field sites, trails, or other potentially contaminated areas. Change clothes or use a removable outer layer (apron, smock, or coveralls) if you will be working with contaminated materials (e.g., cleaning used pots) and in clean nursery areas on the same day. Ensure personal protective equipment is clean and sanitized as appropriate.

6.1.3. Footwear should be cleaned and sanitized before entering clean areas of the nursery. Clean off all soil and detritus first and finish by soaking the soles and contaminated portions of the uppers with a disinfectant (e.g., 70% alcohol).

6.1.4. Use waterproof gloves when possible and clean and sanitize regularly (or discard as needed if using disposables). Use separate gloves for highly contaminated operations such as cleaning used pots.

6.1.5. Leather or fabric gloves are hard to sanitize and keep free of soil particles and should be avoided. Where use of these gloves is necessary, use multiple washable pairs and change into clean gloves if gloves become contaminated or when switching between activities that could result in cross contamination.

6.1.6. Don't allow volunteers or other workers to bring home gardening gloves into the nursery unless they are freshly laundered.

6.1.7. If not using gloves, wash hands thoroughly with soap and water or hand sanitizer (quaternary ammonium or alcohol based) making sure clean off all adhering soil.

6.1.8. Require nursery visitors to follow the phytosanitary procedures that would apply to nursery workers, including clean clothes, shoes, and hands. Don't allow visitors to enter clean areas or handle plants or clean materials without following the appropriate phytosanitary procedures.

6.1.9. Because information related to *Phytophthora* and other pests and diseases continues to expand and recommendations may change, keep in touch with the latest research and regulatory findings through the CNPS website.

6.2. Nursery design, layout, and work flow

Objective: use the design and layout of the nursery to reduce opportunities for introducing contamination into plant stock

What you need to know: The propagation and production areas of the nursery need to be maintained as clean areas. Nurseries also have areas that are not clean: quarantine areas for potentially contaminated plants, contaminated areas where materials from outside of the nursery arrive. Organizing the nursery layout to separate clean and contaminated areas and activities will help reduce opportunities for spreading contamination into clean areas.

Best practices:

6.2.1. Assess the areas adjacent to the nursery to determine whether they could serve as sources of contamination via flowing water, mud flows, blowing soil or debris, or splash from roads or vegetation. Install drainage, fencing, and barriers where appropriate to mitigate contamination from off-site sources.

6.2.2. Consider worst-case conditions (heavy rainfall, high winds, etc.) when designing mitigation measures such as drainage to ensure that these measures will be effective across the whole range of likely weather conditions.

6.2.3. Maximize separation between clean and potentially contaminated areas. Don't situate contaminated areas (e.g., trash bins, dirty pot piles) where runoff, splash, or wind can move contaminated soil, water, or debris into clean areas. Use solid barriers as needed to prevent potential contamination via splashing water if the site is too small to allow separation of at least 10 ft (3 m) between clean and contaminated areas.

6.2.4. Use barriers and controlled access to restrict movement from contaminated to clean and require sanitation at entry points into clean areas.

6.2.5. Keep the size of contaminated areas to a minimum. Use solid surfaces, catchments, and drains to capture and remove contaminated soil, debris, and runoff to minimize opportunities for spread into clean areas.

6.2.6. Use closed bins or dumpsters for disposal rather than cull piles that can serve as sources of contamination. Areas for handling and discarding culls should be outside of the nursery clean areas and should not be located where wind or flowing water could carry contamination into the nursery.

6.2.7. Organize the flow of work in the nursery so that contamination from old plants, containers, and soil won't be spread to clean materials and areas.

6.2.8. Consider how and where deliveries are made and avoid having contaminated vehicles and equipment enter clean production areas. Any vehicles entering clean areas of the nursery should be free of soil and debris.

6.2.9. Use signage at all access points that specify decontamination procedures required before entry. Use signage to emphasize clean working practices.

6.2.10. Establish wash and decontamination stations that are easy to use at all entrances to clean areas.

6.2.11. Make it easy for workers to follow clean production practices. Install hangers to keep hose ends off the ground. Have sanitation supplies such as brushes and disinfectant sprayers staged in convenient spots in working areas or have workers carry these supplies on their toolbelts. Use an easily cleanable cart equipped with sanitation supplies that can be used as a clean working surface in the nursery.

6.2.12. Potting benches and similar areas that need to be decontaminated frequently should be made of nonporous materials that are easy to clean and sanitize.

6.3. Benches and growing areas

Objectives : provide enough space between plants and potential sources of contamination to minimize the risk of contamination via water splash

What you need to know: The ground surface, even if it is covered with gravel or landscape fabric, is nearly impossible to maintain as a clean surface. The common practice of placing containers on the ground is generally not compatible with clean production.

Best practices:

6.3.1. Keep all plants on benches that will keep the bottom of plant pots are at least 2.5 ft above the underlying surface to minimize the risk of contamination via water splashed from the ground surface.

6.3.2. Bench tops should be made of expanded wire mesh or other open materials that do not allow water movement between pots and can be effectively sanitized. Plywood, wood pallets, or similar solid surfaces that allow water to pool or run laterally are not acceptable. Do not use benches that have wide horizontal surfaces that can catch and hold water or debris.

6.3.3. Wood is difficult to keep clean and to sanitize, so its use in nursery benches is generally discouraged. Wood is acceptable in applications such as upright members (bench legs) or other supports that do not catch soil, water, plant debris, etc.

6.3.4. Manage surfaces underneath benches and in walkways and driveways to prevent puddles, eliminate potential for splash, and remain free of weedy vegetation. Maintain adequate drainage and use gravel, landscape fabric, pavers, concrete, or other materials to keep underlying soil covered and avoid having exposed wet soil or mud.

6.3.5. Allow as much space as possible between benches and between blocks of plants within benches to minimize the potential for cross contamination via splash. Where it is not practical to provide a relatively safe gap of about 5 ft (1.5 m), consider using barriers (e.g., made of plastic film, fine mesh, or acrylic sheets) to separate adjacent blocks on a bench. Note that if contamination is detected, all plants within splash distance of a *Phytophthora*-infected plant or block of plants need to be quarantined for further testing or discarded, so maintaining separation helps localize spot infestations to the fewest plants possible.

6.3.6. Increase spacing between pots within blocks where possible to reduce the potential for pot-to-pot splash.

6.4. Tools, surfaces, and the nursery environment

Objectives : use thought and care in all aspects of plant handling to prevent contamination in various plant production and maintenance activities

What you need to know: If in doubt, sanitize surfaces, tools, and hands directly before they are used with clean materials. Some redundancy in maintaining sanitation will not cause harm, whereas skipping sanitation because something is supposed to be clean can lead to accidental contamination. Do not allow water, soil, or debris from contaminated items and surfaces (including the ground) to be transferred to clean plants or surfaces. Avoid moving soil or splashing water between plants.

Best practices:

6.4.1. Provide disinfectant footbaths or other decontamination supplies (brushes and disinfectant sprayers) for sanitizing footwear at all entrances to clean areas. Workers may also use a separate set of sanitized shoes or boots that are used only in the clean area. Sanitize these at least daily.

6.4.2. Items (including workers' gloves or hands) that have been in contact with the ground or other potentially contaminated surfaces or materials must be sanitized before being placed in contact with clean plant materials, pots, soil, or benches.

6.4.3. Do not insert unsanitized items in the plant potting media (including your finger to check moisture). If you need to probe in to the pots of multiple plants, use clean and sanitized tools, implements, fingers, etc., as you move from plant to plant.

6.4.4. Clean and sanitize hands, surfaces, and implements periodically when handling many plants successively in operations such as repotting. Clean and sanitize hands/gloves, tools, etc., when switching between different blocks of plants.

6.4.5. Assign tools and equipment for exclusive use in the clean production area. Heat-treated potting media should also have dedicated clean tools. Provide clean storage areas where tools can be stored off the ground and away from splashing water. Tools and equipment should be stored clean and sanitized before use.

6.4.6. Avoid unnecessary handling, rearranging, and moving of plants. Handling increases chances for contamination. Rearranging plants can obscure patterns that might indicate a disease or pest problem, and can also increase the chances for spread by giving infected plants new sets of neighbors.

6.4.7. Do not place container stock on the ground or unsanitized surfaces at any point. Plants that are potentially contaminated though improper handling should be discarded or moved to a quarantine area and not left in clean areas. It is better to lose one plant than to risk contaminating an entire block.

6.4.8. Place plants and other clean items only on clean or sanitized surfaces if it is necessary to move them. Clean intact sheets of plastic or paper may be used as a clean working surface.

6.4.9. Clean and sanitize benches before placing a different set of plants or other clean items on them.

6.4.10. Remove suspected diseased plants as soon as problems are seen. Transfer to a quarantine area for testing. Note the locations on the bench by leaving empty spots and make notes indicating date,

symptoms, and test results. Monitor and test adjacent plants as appropriate (see 6.6. Inspection and testing below).

6.4.11. Promptly dispose of culls and disposable contaminated materials by placing them in a closed waste container. Do not maintain containers of contaminated waste or culls in the clean area. After use, take them to the waste disposal area and clean and sanitize the container before bringing it back to the clean area. Alternatively, use disposable bags for waste collection, seal, and take directly to the waste disposal area.

6.4.12. Maintain general cleanliness in the nursery by removing plant debris and spilled potting media. Avoid creating dust and splash when cleaning.

6.5. Other cultural inputs

Objective: manage all cultural inputs to minimize the risk of contamination and facilitate rapid detection of root disease if it develops

What you need to know: *Phytophthora*-caused diseases, as well as those caused by many other plant pathogens, are favored by the moist and crowded conditions found in many plant nurseries. Chemicals that suppress *Phytophthora* symptom expression in the nursery do not eliminate *Phytophthora* infections.

Best practices:

6.5.1. Use low water pressure and small droplet sizes when irrigating to minimize splash between containers.

6.5.2. Schedule overhead irrigations to minimize the duration of leaf wetness.

6.5.3. Avoid excessive irrigation or stressing plants with inadequate water. Consider water loss from evapotranspiration, inputs from rainfall, plant and pot size and other factors when scheduling irrigations.

6.5.4. Keep irrigation wands, nozzles, and hose ends at least 3 feet (1 m) off the ground on clean, sanitized hooks or racks. The same standard applies to any portion of a hose that may come in contact with or will be held over plants or benches during use. Resanitize these items after any contact with the ground or other potentially contaminated surfaces. Overhead hose reels (like those used in auto shops) are somewhat expensive, but potentially an easy way to avoid contaminated hoses in a small nursery.

6.5.5. Do not apply materials to plants (e.g., compost tea, organic amendments, organic fertilizers) unless you have reliable documentation that they (a) are free of *Phytophthora* and other pathogens and and (b) have been stored and handled in a way to prevent contamination.

6.5.6. Do not use systemic oomycete suppressive compounds ("fungicides") because they suppress *Phytophthora* but do not eliminate infections. These include fertilizers containing phosphite or phosphonate salts (note: phosphites have suppressive activity against *Phytophthora* diseases; phosphates are fertilizers with no such activity). By suppressing *Phytophthora* symptom development, these chemicals mask introductions of *Phytophthora* into the nursery. When such symptomless but infected plants are planted, the suppressive activity declines as the chemicals degrade. The pathogens can resume activity, leading to both plant decline and infestation of the planting site. See HOW USING FUNGICIDES IN NURSERIES CAN INCREASE THE RISK OF MOVING *PHYTOPHTHORA* TO PLANTING SITES for a more complete discussion on this topic.

6.6. Inspection and testing

Objective: identify potentially diseased material at the earliest possible stage so it can be culled in a timely manner to prevent further spread in the nursery. Note that with clean inputs and clean production practices, the need for testing will be minimized and tests should show no *Phytophthora* detections. If *Phytophthora* contamination is detected in the nursery, you will need to reevaluate your practices (see "7. Record Keeping" below) and look for possible avenues of contamination.

What you need to know: Most of the *Phytophthora* species currently circulating in nurseries cause decay of fine feeder roots. Decay of these roots can result in stunting and drought stress symptoms, as the plant will have reduced capacity to absorb water and nutrients. In nursery situations, plants commonly get plenty of water and nutrients and have low evaporative demand due to shading and high humidity. Under these nursery conditions, plants that are drought tolerant, like many California natives, can survive and show no obvious top symptoms even if they have very few functioning roots. Although visual inspection of the tops is of limited use for detecting root rots, close attention to plant appearance (e.g., off-color) and patterns of growth (e.g., stunting) in a batch of plants can help you spot plants or sets of plants that should be tested. Various *Phytophthora* species, including many that normally cause root rot, can also cause foliar blighting or stem cankers if they are splashed onto shoots and leaves. These shoot and leaf symptoms can be detected by careful inspection, though testing is needed to confirm the cause of such symptoms.

Routine testing for *Phytophthora* in production areas should be conducted by commercial nurseries as a quality control measure. CNPS nurseries with limited resources will generally need to use testing more sparingly. Individual plant tests are warranted when symptoms suggest that plants may be infected. Bench-level tests are needed to follow up on detections and are useful for quality assurance. Not all test protocols are equally useful for all situations. Most tests will identify highly-infected plants, but to detect low levels of disease in asymptomatic plants, the proverbial "needle in a haystack", tests that depend on small samples from one or a few plants will be very inefficient and result in false negatives. See *PHYTOPHTHORA* TESTING PROCEDURES FOR CNPS BMPS FOR PRODUCING CLEAN NURSERY STOCK for more information.

Best practices:

6.6.1. Visually inspect all plants regularly and frequently (e.g., weekly) for poor plant growth or appearance. You can use photos from a fixed point to help compare appearance over time.

6.6.2. Look for patterns of symptoms in the block that may suggest spread from one or more infected plants. This will not be possible if you rearrange plants on the bench.

6.6.3. Remove suspected diseased plants from the clean production area in a manner that will prevent contamination of other remaining plants. In particular, don't let water or potting media from removed containers to fall into other containers or onto clean surfaces. Place pots directly in a plastic bag or clean container before moving.

6.6.4. The positions of culled plants on a bench should remain unoccupied at least until testing has been completed. Quarantine adjacent plants (hold in place without selling or moving) within 3 ft (1 m) of suspected diseased plants until testing is completed.

6.6.5. Remove suspected diseased plants from the clean area to a contained, cleanable surface to inspect the root system. Look at as much of the root system as possible by separating roots from the potting media; rinse with water if needed to see roots more clearly. Roots with severe *Phytophthora* root rot may have roots that appear discolored, mushy or decorticated (outer soft tissues slough off, leaving only the woody vascular tissues). In less decayed roots, you many only see decay or discoloration of small side roots or newly-emerging root tips and overall root growth may be less than expected. There may be areas of apparently healthy roots and others that show decay. At early stages of disease or in some species it may be difficult to see any clear symptoms of disease.

6.6.6. Plants with possible disease symptoms and surrounding plants should be tested for the presence of *Phytophthora*, or other pathogens if appropriate (see *PHYTOPHTHORA* TESTING PROCEDURES FOR CNPS BMPS FOR PRODUCING CLEAN NURSERY STOCK).

6.6.7. If *Phytophthora* is detected within a block of plants, you will need to determine whether the contamination is related to the batch or is related to the block (see definitions). If possible, use bench level testing (see *Phytophthora* testing procedures document) to test the suspect block and other materials from the same batch that may be in other blocks.

6.6.8. Dispose of all plants in contiguous blocks that test positive for *Phytophthora*. Quarantine and continue to test adjoining blocks until you determine the limits of the infected plant material. Plants adjacent to a detection can be considered uninfected if no detections are made in two successive tests conducted at least 2 weeks apart under suitable test conditions.

6.6.9. Thoroughly sanitize bench surfaces, irrigation equipment, and other items and surfaces that may have been in contact with *Phytophthora*-infected plants.

6.6.10. Seek diagnostic help from qualified experts if you encounter unfamiliar pests or disease symptoms.

6.6.11. Bench-level testing (see *PHYTOPHTHORA* TESTING PROCEDURES FOR CNPS BMPS FOR PRODUCING CLEAN NURSERY STOCK) can be used to test for the presence of *Phytophthora* in blocks of plants that do not show obvious symptoms as a quality control check. Rotate the testing among blocks, with emphasis on plant material that has been in the nursery the longest.

7. Record keeping

Objective: maintain records that help verify that inputs are clean and nursery workers are complying with clean production practices and facilitate traceability of materials used for the production process.

What you should know: Well-documented, consistent records are a key element of any certification systems and are needed to document that a nursery is following clean production practices. Although CNPS nurseries generally are not selling to clients that require this documentation, adequate records and documentation are a key tool of any nursery following a clean production system. Where multiple workers are involved, records show who did what and when. This information helps the nursery manager monitor working practices, and also provides a way to trace back problems that may arise in one or more batches of plants. Having good records can mean the difference between a quarantine of the entire nursery to track down a *Phytophthora* infestation and focusing on a small group of plants that may have been exposed to a particular lapse or exception.

Some areas of record keeping to consider are listed below. A useful way to organize much of this information is to maintain planting-to-sale records for each separate batch of plants that allows you to quickly review all of the inputs and cultural practices during production as well as plant health issues that have been observed.

What to consider:

7.1. Planting materials: Dated logs noting collection locations or sources, propagule types, storage (e.g., dates, locations, temperature) and treatment (e.g., dips, heat treatment) parameters.

7.2. Containers: Dated logs of type of pots and flats used (new or reused) for each batch of plants. If reused containers are used, note cleaning and sanitation details (when treated, by whom, how).

7.3. Potting media: Dated logs indicating the source and treatment of potting media, (including time and temperature data).

7.4. Water: documentation of water supply used, including practices used for maintaining wellhead integrity, if applicable. If using municipal sources, you may only need to make note of when maintenance occurs, such as repairing broken pipes, etc.

7.5. Production practices: Dated logs should include records for testing or refreshing disinfectant solutions (post a log sheet near the site), plant health inspections, checklists, and other records used to emphasize and maintain clean production practices.

7.6. Testing: Keep track of which batches or individual plants have been tested, where they were located in the nursery, and dated results. Indicate what happened to the plants and any follow-up or determinations as to the source of identified detections.

7.7. Plant batches: Use pot labels to identify each plant batch. The batch number should allow you to identify the type and source of plant propagules used, dates of potting and repotting, type of potting media used and how/when it was treated, testing, and other production inputs and handling. This information is critical for tracing potential sources of contamination if plants in a given batch are found to be infected.

7.8. Worker training: If you have multiple workers or volunteers, keep track of training that was conducted (when, by whom, topics). Make sure nursery workers have read BMPs and other related materials and have enough training to follow them. Keep copies of BMPs and related references available for quick reference in the nursery.

8. Taking plants to off-site sales

Objective: Follow phytosanitary procedures to maintain clean stock until it has been transferred to the customer.

What to know: Cleanliness of nursery stock is your responsibility until the plants have been delivered to the customer. If you want to take unsold plants back into the nursery, you must be sure that they have not been exposed to potential contamination. Plant sales may be located in potentially infested landscaped areas and involve participation by volunteers who are unfamiliar with BMPs for preventing plant diseases and who may show up with contaminated footware, gloves, and equipment.

Best practices:

8.1. Workers should follow the phytosanitary protocols and principals already explained in this document to prevent contamination of plants as they are moved back and forth in vehicles or carts for delivery.

8.2. Place plants only on clean sanitized surfaces for transport and display. Do not move plants in unsanitized carts or wheelbarrows. Be sure to sanitize handles.

8.3. Clean paper or plastic sheeting can be used to provide a clean surface as long as these materials are intact.

8.4. Only plants that have been handled under phytosanitary conditions in clean vehicles can be considered for return to clean areas of the nursery. Even then, such material should be kept separate from other plants and not mixed back into clean production blocks.

8.5. Plants displayed to the public and handled by them should be discarded if not sold or returned to a quarantine area outside of the nursery clean area. These plants should remain in quarantine until sold and delivered or discarded. To minimize the number of plants in this situation, minimize the number of plants put out for display, keeping other stock stored in clean vehicles until needed.