GF Extension

SYSTEMS-BASED APPROACH TO PEST MANAGEMENT: A QUICK REFERENCE GUIDE

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University of Tennessee

SOUTHERN EXTENSION RISK MANAGEMENT EDUCATION

USDA

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Further Reading:

Scouting and Monitoring Pests of Deciduous Trees during Nursery Production

https://utextension.tennessee.edu/publications/DocumentsW142.pdf

UT Soil, Plant and Pest Center—Insect and Plant Disease Information Sheet

https://ag.tennessee.edu/spp/Forms%20and%20Information%20Sheets/insectplantinfo.pdf

Digital copy of this quick reference guide is available at:

http://plantsciences.utk.edu/fulcher_systems_pstmgtwkshp.htm

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Content for the Systems-based Approach to Pest Management: A Quick Reference Guide was adapted from the following:

Griesbach, J.A., J.L. Parke, G.A. Chastagner, N.J. Grünwald, J. Aguirre. 2012. Safe production and procurement manual: A systems approach to the production of healthy nursery stock. Available at http://grunwaldlab.cgrb.oregonstate.edu/sites/default/files/SafeProduction.pdf.

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soil plant and pest center

UT Extension

Microscopic and Baiting Technique for the Identification of *Thielaviopsis basicola*

Microscopic Examination

Thielaviopsis basicola is an economically important fungal pathogen of agricultural and horticultural crops such as tobacco, holly and pansy. *Thielaviopsis* is the causal agent of black root rot (Figure 1). Symptoms include stunting, foliar chlorosis and dark,

Figure 1. Chlorotic pansy plugs infected with black root rot.

decayed roots. The most common sign of disease is the presence of multi-celled chlamydospores (Figure 2) in root tissue.

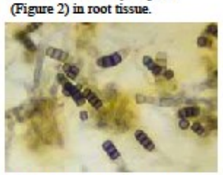

Figure 2. Thielaviopsis chlamydospores in pansy root tissue (400X).

To examine roots for Thielaviopsis, wash away potting media and examine roots for blackened areas with a dissecting microscope (Figure 3). Remove blackened roots. Mount on a glass slide in a drop of water and cover with a cover slip. Examine with a compound microscope at 100X and 400X (Figure 4).

Figure 3. Blackened roots of panys infected with Thielaviopsis (60X).

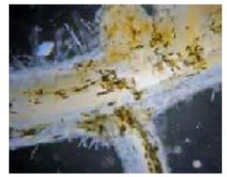

Figure 4. Chlamydospores in a pansy root (200X).

Baiting Technique for Isolation of Thielaviopsis

Chlamydospores are not always visible in root tissue infected with Thielaviopsis. To confirm the presence of the fungus, suspect roots may be washed and placed on carrot slices in a Petri dish (Figure 5) with moistened filter paper or paper towels to keep humidity high. Incubate for 5-7 days and examine with a dissecting microscope for presence of chlamydospores (Figure 6) . Remove a small piece of carrot tissue with chlamydospores and examine with a compound microscope at 100X and 400X (Figure 7).

Figure 5. Carrot discs with black mycelial growth of *Thielaviopsis*.

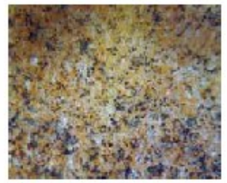

Figure 6. Thielaviopsis chlamydospores on carrot tissue (60X).

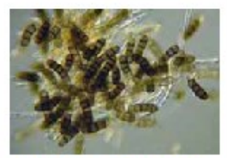

Figure 7. Thielaviopsis chlamydospores (400X).

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Scouting

- [ ] Hand lens or magnifying visor for hands-free inspection
- [ ] Clipboard
- [ ] Flagging tape and/or field flags to mark infested plants
- [ ] Sticky cards
- [ ] Marking stakes
- [ ] Data forms—quantify insect counts and map infestations
- [ ] Nursery map
- [ ] Resealable bags for collecting plant samples
- [ ] Vials filled with alcohol for collecting insect and mite samples

Sanitation Supplies

- [ ] Sanitizer (see page 39)
- [ ] Gloves
- [ ] Sanitation mat/footbath
- [ ] Spray bottle

Introduction

Growers must contend with several insect pests and plant pathogens that threaten their nursery crops and limit trade due to quarantine restrictions. The increase in global trade is bringing additional pest and pathogen species to our country every year, and climate change is resulting in habitat shifts that make it difficult to predict future pest outbreaks and disease epidemics.

Rather than develop piecemeal strategies for combatting each pest and pathogen after they are established, the systems-based approach is designed to reduce the risk of contamination by pests and pathogens using a holistic, preventative approach. This quick reference guide arose from a September 2013 grower workshop organized by Drs. Diana Cochran, Amy Fulcher, Frank Hale, and Alan Windham. It highlights the most important steps Tennessee growers can take to implement a systems-based approach for pest management. I commend them, and you the growers, for taking a proactive approach to safeguard your nursery crops.

Dr. Jennifer Parke
Oregon State University

Shipping and Receiving

Propagating plants in house is a good first line of defense against unwanted insects, diseases, and weeds. If purchasing plants be sure to buy from reputable, certified or licensed nurseries and inspect upon arrival. Quarantine any plant that is suspected to be infected or infested. Parke and Lucas (2008) reported the spread of *Phytophthora ramorum* between plants spaced less than 2 ft apart, so make sure quarantined plants are spaced far enough away to prevent spread to uninfected plants.

Concrete shipping and receiving pad.

When shipping plants, be sure to follow all shipping regulations. Do not ship plants if you suspect it is infected or infested with injurious pests. Remember, your plants, your name, your reputation! For additional information see page 11.

Propagation

There are many insects, mites, diseases, and/or weeds that intrude upon nurseries and to learn them all would be quite challenging. Therefore, focus on learning the top ten problems at your location. A good way to learn potential problems, is to have photos of them posted in common areas, such as break rooms. Additionally, remember to start with disease-free plants and to routinely disinfect propagation tools. It only takes one pruning cut on one infected plant, to infect up to 21 plants as they are pruned (Bausher, 2013). And, diseases can result from living organisms (fungi, bacteria, viruses) and/or nonliving factors (temperature, water, mechanical damage), so monitoring the propagation environment can help reduce plant susceptibility to both abiotic and biotic disease. For additional information see page 16.

Reference Guides: 2. Scouting Recordkeeping

Date Received: _____ Inspection Date:_____

Source: _____ Inventory #: _____

Type: _____

Pests or Pathogens Found: _____

_____

House/Field/Container Pad: _____

Parts affected:

- ☐ Roots
- ☐ Leaves
- ☐ Fruits
- ☐ Stem
- ☐ Flowers

Distribution

- ☐ General
- ☐ In Rows
- ☐ In High Areas
- ☐ Scattered
- ☐ In Spots
- ☐ In Low Areas
- ☐ Certain Variety
- ☐ Other

Appearance

- ☐ Wilted
- ☐ Stunted
- ☐ Dead Leaf Area
- ☐ Yellowed
- ☐ Leaf Spot
- ☐ Plant Distortions
- ☐ Dead Plants
- ☐ Leaf Mottle/Mosaic

Reference Guides: 2. Recordkeeping: Incoming Stock

Date Received: _____ Inspection Date:_____

- ☐ accepted, no action required
- ☐ accepted, pesticide treatment required
- ☐ accepted, quarantined

Source: _____ Inventory #: _____

Type: _____

Pests or Pathogens Found: _____

_____

Parts affected:

☐ Roots	☐ Leaves	☐ Fruits
☐ Stem	☐ Flowers	

Distribution

☐ General	☐ In Rows	☐ In High Areas
☐ Scattered	☐ In Spots	☐ In Low Areas
☐ Certain Variety	☐ Other	

Appearance

☐ Wilted	☐ Stunted	☐ Dead Leaf Area
☐ Yellowed	☐ Leaf Spot	☐ Plant Distortions
☐ Dead Plants	☐ Leaf Mottle/Mosaic	

Production

Container

Reusing containers can be a great way to save money, reduce petroleum and energy consumption, and limit agricultural plastic in landfills. However, containers can be a source of pathogens, arthropod pests, and weed seeds. Handling containers carefully is an important component to using systems-based pest management to preventing pests of all types. For additional information see page 19.

Production

Field

Many nursery crop growers produce plants in field soil, not containers. Field soil can become contaminated with pathogens that persist for many years such as those that cause phytophthora root rot, verticillium wilt, and southern blight. Some soil-borne pathogens can move downhill as water drains, infesting new areas or these pathogens can be carried by employees or equipment such as tractor or wagon tires, to non-infested areas around the nursery. For many of these pathogens, fungicidal remedies are not practical or economical. For example, fumigating a two acre field can range from $1808 to $2534 versus a ten acre field which can costs upwards of $9040 (Sydorovych et al., 2006). In the latter case, it is best to prevent diseases rather than try and control large fields. For additional information see page 22.

Field production of 'Autumn Blaze' red maple.

Water Management

Plant growth depends on properly managing irrigation. Too much or too little irrigation can compromise plant health and predisposes plants to disease, especially root rots, as well as mite and insect problems. Water can also be a source of pathogens that cause disease. Pathogen-infected water can come into contact with plants as puddled water on the ground or directly through irrigation applications. The Oregon Department of Agriculture found irrigation water (and substrate) to be the greatest sources of contamination for *Phytophthora ramorum*, the pathogen that causes sudden oak death! Water quality also impacts plant health. For example, a water supply with high pH and alkalinity may lead to nutrient deficiencies. Knowing how to manage water resources and irrigate properly is an important component to using systems-based pest management to prevent pests of all types. For additional information see page 25.

If using pond or recycled water for irrigation, test monthly for *Phytophthora* sp.

Site Maintenance

Maintaining both your crop and noncrop areas is vital to a systems-based approach to pest management. Standing water in and around production areas creates an environment for disease. Weeds in surrounding areas can disperse their seed through wind or by hitching a ride on equipment, shoes, etc. This can pose a serious problem if weed seed contaminates substrate/media piles. In theory, if a single seed germinates in a substrate pile and goes unnoticed, thousands of seed from this one plant can infiltrate thousands of newly potted containers. For additional information see page 27.

Systems-based Pest Management Check List

UT Extension — Tennessee State University

Maximizing your potential; minimizing you risk

- ☐ Unused containers are stored off ground and above the rain splash zone
- ☐ Sterilize all used containers and flats before planting
- ☐ Disinfect surface water that is used for irrigation
- ☐ Sanitize hands and shoes before entering a propagation area
- ☐ Keep clear records that allow plant history to be traced
- ☐ Quarantine new plants before moving them into the nursery
- ☐ Plants are grouped and spaced appropriately
- ☐ Plants are scouted weekly or bi-weekly during production
- ☐ Sanitize pruning equipment regularly when pruning or shearing
- ☐ Cull piles and plant debris are kept out of the production area

Southern Risk Management Education Center

USDA United States Department of Agriculture National Institute of Food and Agriculture

Sanitation/Sterilization Guide:

3. Treating Infested Water

- Ultraviolet radiation
  - 250 mJ/cm² eliminates most pathogens
  - 500 mJ/cm² kills *Phytophthora*, *Pythium*, *Colletotrichum*, and *Fusarium*
- Heat Treatment
  - Heat water to 203°F for 30 sec
- Chlorine Gas
  - 0.5 to 2 ppm free chlorine (2 ppm controls zoospores of several *Pythium* and *Phytophthora* species)
- Chlorine dioxide
  - Sanitation (continuous use): 0.25 ppm at water outlet
  - Shock treatment: twice a year to treat lines or tanks at 20 to 50 ppm depending on product
- Ozone Treatment
  - 10 grams per hour per cubic meter
- Hydrogen dioxide/activated peroxygen
  - Follow product labels (ex. ZeroTol, SaniDate, Xeroton-3)
- Sodium hypochlorite (liquid bleach)
  - 0.5 to 2 ppm free chlorine (2 ppm controls zoospores of several *Pythium* and *Phytophthora* species)

http://www.watereducationalliance.org/keyinfo.asp

Site Maintenance

Substrate/Potting Media

Managing substrate inventories is an important part of systems-based pest management. The Oregon Department of Agriculture (ODA) found more *Phytophthora ramorum*, the pathogen that causes sudden oak death, in substrate, along with water, than any other point of contamination within a nursery! Other pathogens, weeds, insects, and mites can also gain a foothold in production from substrate, new or used. How substrate is stored is one of the most critical stages in the production chain. Poor substrate storage conditions can not only lead to pathogen contamination but can also lead to anaerobic conditions within the substrate, the development of hydrophobic mold, extremely low substrate pH, and related problems with plants during production all of which can weaken plants, making them more susceptible to pathogens, insects and mites. For more information see page 28.

Substrate storage area with concrete pad and wall.

Site Maintenance

Weed Control

Like most plants, weeds favor certain environments. For example, bittercress can be a major problem in drainage/run-off areas because it prefers a cool, moist environment (Neal and Derr, 2005). One plant can produce 5,000 seed (Bachman and Whitwell, 1995) so by maintaining non-crop areas and by preventing weeds from going to seed, you can help keep bark piles and production areas weed-free. In the picture on the right, bittercress has taken over the containers on the outside of the block while the rest of the containers are free of bittercress. For more information see page 30.

Bittercress in border containers.

Integrated Pest Management

Scouting

Integrated Pest Management and systems -based pest management have some similarities including employee training and scouting. Scouting allows early detection of insects, mites, diseases, and weeds before they become problematic. And, it is much easier to control small populations than it is to control large populations and young insects than mature ones. This timely detection can improve plant quality, reduce plant damage, and prevent production delays. Once detected, an appropriate management tactic is necessary to prevent outbreaks. See page 33.

Integrated Pest Management

Employee Training

Training employees is an important component to systems-based pest management. Employees are often the first line of defense against pests and are working in all areas of receiving, propagation, production and shipping so their reach spans the entire nursery. Employees can be trained and rewarded for making the effort to detect pests during their assigned tasks. Additionally, their sightings can be used to inform others and/or supplement records that improve future scouting and pest management tasks. For more information see page 34.

Recordkeeping

Keeping records will allow plants to be easily traced should a problem present itself. It is important to keep records of dates that plants arrive, scouting dates, and any disease/pest problems encountered while scouting. Records should be kept for incoming and outgoing plants, propagated plants, and plants in production. Keep records in a location that is easily accessible by management. For more information see page 35.

Sanitation/Sterilization Guide

2. Tools and Equipment

- Alcohol dips
  - Isopropyl (70%): 1 part isopropyl: 1 part water
  - Denatured ethanol (95%): 1 part ethanol: 1 part water
- Sodium hypochlorite (Clorox Bleach)
  - 1 part bleach: 9 parts water
- Lysol
  - 1 part Lysol: 4 parts water
- Pine-Sol
  - 1 part cleaner: 3 parts water
- Green-Shield
  - Cutting tools: 1 TSP: 1 quart of water
  - Benches: 1 TBSP: 1 gallon of water

Note: When pruning, have 2 tools so that one can soak in disinfectant while the other is in use.

Note: Alcohol and bleach are corrosive to metal and are not recommended.

http://baker.ifas.ufl.edu/Horticulture/documents/DisinfectingPruningTools.pdf

http://puyallup.wsu.edu/~Linda%20Chalker-Scott/FactSheets/Pruning.pdf

Sanitation/Sterilization Guide

1. Pots

- Aerated steam
  - 140°F for 30 minutes
- Hot water dip
  - 180°F for 30 minutes
- Soak containers in disinfectant
  - 1 part bleach: 9 parts water for a minimum of 10 minutes
  - 1 TBSP Green-Shield: 1 gal of water and soak for 10 minutes
  - 1 part ZeroTol: 100 parts water or a 1:300 dilution
- Alternative
  - Wrap clear plastic sheeting around a bin of used pots in a sunny location for several weeks.
    - Sustained temperature greater than 131°F for 15—21 days (Griesbach et al., 2011)

Note: Prior to using one of the aforementioned sterilization options (excluding solarization), remove as much debris from the used containers as possible.

SHIPPING AND RECEIVING

Protect your plants by wrapping shipping crates with plastic wrap to help reduce plant damage during shipping. And, having a shipping dock made of concrete makes it easy to clean.

- Shipping
  - Nursery Licenses
  - Federal Regulations
  - State Regulations
- Receiving
  - Inspect Plants
  - Recordkeeping
  - Sanitation

Shipping Area

- Nursery Licenses
  - Be aware of state laws, many states require proof that plants are sold and shipped from a licensed nursery.
- Federal Regulations
  - A Nursery Stock Certificate to ship in- and out-of-state.
  - Verify that the phytosanitary certification meets the requirements of the location being shipped to.
  - Verify that shipments are free of quarantine pests and/or injurious pests.
- State Regulations
  - Individual states can have regulations independent of federal regulations.
  - A list of state regulations can be found at:

    http://www.nationalplantboard.org/laws/index.html

Keeping digital records allows multiple members of management to access the information.

SANITATION/STERILIZATION

Starting with clean pots, tools, and water is a good first line of defense against pests and pathogens. Here are some guidelines that can help you develop a good sanitation/sterilization program.

1. Pots/Containers/Flats/Cell Packs
2. Tools and Equipment
3. Water

- Incoming Stock
  - At delivery and before unloading, inspect and record any suspicious material.
    - Inspect packing material and the inside of the delivery vehicle for hitchhikers such as slugs, snails, ants, fungus gnats, and other pests.
- Propagated Plants
  - Records should be kept on stock plants, cuttings, and date (including time) cuttings were stuck.
- Production Cycle
  - Keep inventory numbers along with production dates.
  - Scouting: record scout name and date, pest species, life stage, and population size, biological control species, host plant resistance among cultivars, weather, and level of control achieved from previous control measures.
    - Maintain records of when and who applied herbicides, insecticides and/or fungicides.
- Have records easily accessible for members of management.
- See Reference Guide #2 (incoming stock pg. 43; general records pg. 44).

Receiving Area

- Inspect Plants
  - Quarantine any suspicious plants before it enters your production area.
    - Determine if it is a quarantine pest[1] (send to a diagnostic lab if unsure).
    - Dispose of regulated pests according to regulations.
    - If unregulated pest, take proper control measures.

Bareroot holly liners inspected upon arrival were found to be infested with Southern red mites. Early detection and quarantine prevented the spread to existing nursery stock.

- Recordkeeping
  - Maintain records that will allow you to trace back plants should problems arise (see reference guide #2 pg. 43).
- Sanitation
  - Minimize spread of pests by frequently cleaning docks, carts, tractors, etc.

[1]Quarantine pests—pests of economic concern, likely to be moved artificially into endangered zone, currently being officially controlled, could survive in the endangered zone.

Regulations

Follow all state and Federal regulations.

- USDA Animal Plant Health Service Plant Protection Quarantine (USDA APHIS PPQ)
- States Department of Agriculture
- National Plant Board

RECORDKEEPING

Keep thorough records that will allow you to trace back the history of your plants, should a problem arise. Here are some examples of information to record.

- Incoming Stock
- Propagated Plants
- Production Cycle
- Have Records Readily Available

Training

- Assign various System-based Pest Management responsibilities to employees; make sure everyone knows their responsibilities.
- Post top ten insects, mites, diseases, and weeds in employee break or meeting rooms.
- Post sanitation reminders around break areas.
- Establish thresholds and a recordkeeping system for accepting and rejecting incoming plants, and how to dispose of plants during production.
- Attend and bring employees to Cooperative Extension Service and industry association educational programs.
- Complete and encourage employees to complete the Tennessee Master Nursery Producer Program.

Indoor education sessions are a great way to introduce new practices and train employees on adopting systems-based management approaches.

Attending hands-on workshops sponsored by the Cooperative Extension Service is a another great way to train and educate employees on new practices.

- Provide employees with IPM*Pro*, IPM*Lite* or other apps that apply to your business.
- Provide in-house trainings seasonally.
- Offer a reward system for finding/reporting pests.
- Provide brief updates on relevant pests at weekly staff meetings.

- USDA APHIS PPQ
  - Safeguards agriculture and natural resources from the entry, establishment, and spread of animal and plant pests and noxious weeds into the United States of America; and supports trade and exports of U.S. agricultural products. More information is available at:

    http://www.aphis.usda.gov/plant_health/index.shtml
- State Department of Agriculture
  - Individual states regulate the movement of nursery stock, general nursery certification, and quarantine pests within their state. More information is available at:

    Tennessee Department of Agriculture

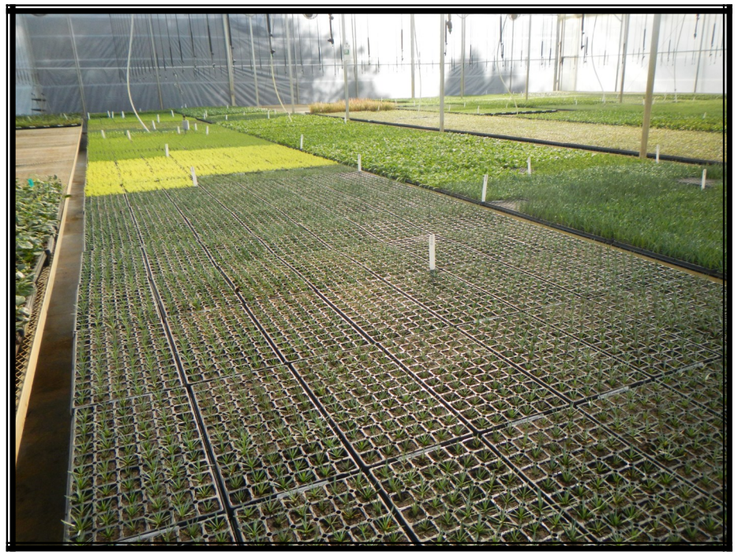
    http://www.tn.gov/agriculture/regulatory/plants.shtml

    Link to other State Department of Agriculture websites

    http://www.rma.usda.gov/other/stateag.html
- National Plant Board
  - Nonprofit organization of the plant pest regulatory agencies of each of the states and the Commonwealth of Puerto Rico. With the purpose to provide national representation for the Eastern Plant Board, the Southern Plant Board, the Central Plant Board, and the Western Plant Board. More information is available at:

    http://www.nationalplantboard.org/

DISEASE MANAGEMENT DURING PROPAGATION



Propagating on-site is a great first line of defense against pathogens. To help mitigate production risk associated with propagation, here are some guidelines to follow.

Best Management Practices for Preventing Diseases during Propagation:

- Train Employees to Recognize Disease Problems
- Start with Disease-free Plants
- Keep Cuttings Stress-free
- Keep Propagation Areas and Tools as Clean as Possible
- Limit Access to Propagation Areas

Scouting

- Choosing the Scout
  - Train and dedicate one person to scout and have one to two backup scouts.
  - Choose from your most dedicated and reliable employees; often, this will be the same person who does the pesticide applications.
- Action Plan
  - Determine frequency of scouting; weekly is optimal for detecting pests such as borers and scale in time to prevent damage.
  - Randomly select plants from all areas of the block.
  - Determine the optimal time to scout for each pest using alerts from the mobile app, IPM*Pro*.

    http://wiki.bugwood.org/SNIPM
  - Scout efficiently using precise, pest-specific protocols found in Scouting and Monitoring Pests of Deciduous Trees during Nursery Production.

    https://utextension.tennessee.edu/publications/Documents/W142.pdf
  - Record and identify all insects, mites, and diseases found and mark any plant deemed unusual.
  - Management should be informed of all infected or infested plants.
  - Unusual and unrecognizable pests and pathogens should be submitted to diagnostic labs.

See pg. 45 for a list of scouting equipment

INTEGRATED PEST MANAGEMENT

Early detection of pests can help prevent spread throughout the nursery. Here are some guidelines that can help you develop a successful integrated pest management program.

- Scouting
  - Choosing the Scout
  - Action Plan
- Training

- Train Employees to Recognize Disease Problems
  - Post photos of the top ten problems for your crops. Include…
    - ⇒ name of the problem, where found, action to take if found, and who to contact.
  - Images of current disease problems can be found at the UT Soil, Plant and Pest Center's Facebook page:

    https://www.facebook.com/SoilPlantPestCenter

    or

    http://www.ipmimages.org/
- Start with Disease-free Plants
  - Take cuttings from stock plants that are free of leaf spots, blight, symptoms of viral diseases, and symptoms of nematode infestation of roots or leaves.
  - Stay aware of new threats to ornamental plants such as: boxwood blight, hosta virus x, canna yellow mottle virus, foliar nematodes, crown rot of liriope, etc.
- Keep Cuttings Stress-free
  - Monitor temperature of propagation areas to prevent heat stress which could increase susceptibility to black root rot, caused by the fungus, *Thielaviopsis basicola* (common problem on Japanese holly, blue holly, and inkberry).
  - Be sure to use a well drained propagation mix.
  - A simple carrot disc assay can be a useful tool to detect the presence of *Thielaviopsis* (See pg. 46) and lateral flow ELISA kits can check leaf lesions or decayed roots for *Phytophthora*.

- Keep Propagation Areas and Tools as Clean as Possible
  - Get off to a great start by using soilless mix, new or clean flats, cell packs or pots.
  - Protect this investment by keeping hose nozzles off the ground, having footbaths of disinfectants at entrances and by keeping flats of cuttings on gravel or raised benches.

Use benches and tools that are easy to disinfect.

  - If reusing pots or flats, be sure to wash off soil and potting mix, then soak in disinfectant (See pg. 38).
- Limit Access to Propagation Areas
  - Limiting foot traffic will help minimize the movement of plant pathogens from fields or other propagation areas by allowing only employees with specific tasks into propagation areas.

- Biological
  - Knowing germination requirements for weed species can aid in preventing conducive habitats in non-crop areas (light, dark, length of time, etc.).
  - Be proactive by keeping records of weed species and time of emergence in preparation for the following season.
- Chemical
  - Read the label, if herbicide is not properly applied it can be ineffective.
  - A successful chemical program starts with an applicator who knows the appropriate herbicide for the weed species and situations, the timing of application, appropriate rate and uniformity of application, and general herbicide knowledge.

Liverwort growing around propagation flats can pose a serious problem. Altland et al. (2007) reported *Marchantia polymorpha* as an economically important weed in nursery crop production. Liverwort can reproduce sexually or asexually. Replacing container mats that show wear and tear can help reduce weeds from infiltrating the mats. And, in propagation areas where the environment is conducive for bittercress, liverwort, etc. try to cover the entire ground surface around the production area.

Weed Management

Maintaining weed-free driveways helps control weeds in crop areas.

- Practices
  - Combine sanitation, biological information, and chemical control techniques to optimize your weed control program.
  - Preventing habitats that are conducive to weed germination and growth is key to a successful weed control program.
  - Display posters and/or guides to help employees recognize common weed problems and how to manage the problem.
- Sanitation
  - Start with weed-free liners
  - Keep non-crop areas weed-free (roadways, drainage ditches, substrate/media piles, etc.).
  - Wash pots and trays before reuse.
  - Wind breaks around the nursery can minimize incoming weed seed from surrounding areas.

Bittercress in loropetalum liner.

Note: Weed seed can easily be spread by wind, foot traffic, un-washed pots, equipment, rodents, etc.; weeds can also serve as alternate host to diseases and insects.

CONTAINER PRODUCTION

Container production is sometimes favored over field production because it requires less space; however, producing multiple plants in close proximity to each other can result in pathogens spreading quickly around the nursery area. Following some of these guidelines can help mitigate production risk associated with container production.

Container Production

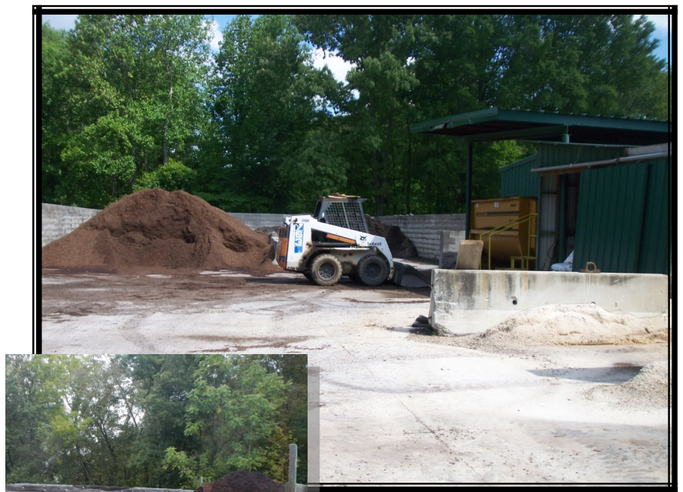
- Container Storage
- Production Practices
  - Disease Management
  - Drainage
  - Sanitation

Containers not properly stacked.

Good example of properly storing containers; off the ground, above rain splash zone and surrounding area free of weeds.

- Container Storage
  - Be especially careful handling and treating used containers from other nurseries.
  - Disinfest all containers before reusing.
  - Wear gloves to avoid contamination during handling.
  - Store containers off of the ground and either on a raised support or on gravel so that rain cannot splash contaminated soil onto containers.
  - Do not allow weeds to go to seed near container storage.
- Production Practices
  - Disease Management
    - Provide gravel and/or landscape fabric barrier under pots so that containers do not contact soil.
    - Isolate production area away from propagation and receiving area.
    - Have adequate spacing between plant groups to prevent spread of disease from infected to uninfected plants.

- Sanitation
  - Dedicate a front end loader to substrate handling so the tires do not come into contact with soil.
    - ⇒ If a front end loader can not be dedicated, wash soil from tires before returning it to the substrate pad.
  - Prevent used substrate from contaminating new, unused inventories.
  - Promptly dispose of or disinfest used substrate.



Top: concrete substrate pad with good drainage and a front end loader dedicated to potting area; Left: concrete pad with improper slope causes water to drain towards pile.

Substrate/Potting Media

It is important to know and trust your source for substrate. Purchasing substrate that is not weed-free can be a costly investment. In the above picture, the group of plants on the left contains weeds and the group of plants on the right are weed-free. Both groups are grown in the same house but potted up using different batches of substrate.

- Source
  - Purchase weed, pathogen, insect and mite-free substrate.
    - Properly composted materials should be pathogen and weed seed free.
    - Most pathogens are controlled at 131°F for 15-21 days.
    - To kill all plant pathogens including resistant viruses, compost should be heated to 149°F for 21 days.
- Storage
  - Store substrate on a concrete pad with good drainage.
  - Ensure that substrate storage is away from cull piles, sick plants, and quarantined shipments.
  - Turn substrate piles periodically and remember to monitor the temperatures inside the pile.
  - Prevent weeds from growing and going to seed in and near the substrate inventory.

- Drainage
  - Create crowned container pads for maximum surface drainage.
  - Properly grade and manage irrigation so that water does not puddle.
  - Install tile under container pads for internal drainage, if necessary.
  - Raise containers off of the ground, if necessary, to avoid contact with standing water.
- Sanitation
  - Remove plant debris and diseased and/or dead plants promptly.
  - Remove unsold, overgrown plants from production or “upsize” promptly.
  - Prevent weeds from growing and going to seed near container production.

Top left: crowning beds help maximize surface drainage; top right: using nonporous material as container mat prevents good drainage; bottom left: to prevent plants from sitting in puddles of water, raise them off of the ground.

FIELD PRODUCTION

Frequently scout fields for pests and pathogens; if pests or pathogens are present but left unchecked, they can spread rapidly throughout the nursery. Here are some guidelines that can help mitigate production risks associated with field production.

Field Production

- Production Practices
- Disease Management
- Irrigation and Drainage
- Sanitation

SITE MAINTENANCE

Maintaining non-crop areas can help prevent unwanted pests and/or pathogens. Here are some guidelines that can help mitigate production risks associated with site maintenance.

Site Maintenance to Minimize Disease Problems

- Substrate/Potting Media
  - Source
  - Storage
  - Sanitation
- Weed Management
  - Practices
  - Sanitation
  - Biological
  - Chemical

- Water Quality
  - Test regularly for pathogens, pH and other indicators that can affect plant health.
  - Disinfest water that is collected from production areas and reused.
- Drainage
  - Prevent standing water by crowning beds and grading roadways, replacing gravel as needed.
- Irrigation
  - Group plants in zones based on water requirements.
  - Use substrate moisture sensors, plant weight, leaching fraction, or other techniques to refine irrigation timing and volume.

Plants grouped in zones based on water requirements and monitored with moisture sensors can help refine irrigation timing and volume.

  - Use a sensor to delay or offset irrigation following rain events.
  - Use the pour-thru technique to monitor pH and salts in the container substrate.
  - Consider cyclic irrigation that includes applying irrigation in the afternoon to maximize growth and possible plant health benefits.
  - Time last irrigation application so that foliage dries before sunset.
  - Check distribution uniformity; replace worn nozzles, etc., in order to reduce over/under irrigation that may occur in some areas of the zone.

- Production Practices
  - Do not plant in infested soil; alternatively, rotate to a crop that is highly resistant or tolerant to the pathogen.
  - Plan for breaks between plants when lining out fields so that fewer plants are damaged/quarantined/destroyed if a regulated pest is detected.
  - Adopt row/driveway spacing that accommodates air assisted sprayer passage and allows spray penetration to the most interior point.
    - To ensure that spray penetration is adequate use water sensitive paper in interior rows to verify coverage.
- Disease Management
  - Train your employees to promptly remove plant clippings.
  - Regularly inspect plants and send symptomatic plants to be accurately diagnosed.
  - Prepare and follow management plan for how to dispose of infested, infected, or otherwise unhealthy plants depending on threat of spread, pest-specific regulations, etc.
  - Be sure to destroy culled plants promptly; burn piles can serve as a reservoir for insects, mites, and pathogens.
    - Modify trailer or cart to prevent debris from falling en route to burn piles.

- Irrigation and Drainage
  - Irrigate as needed to promote plant health.
  - Prevent standing water by using drain tiles and filling holes from harvested plants.
- Sanitation
  - Remove unsold plants or plants that will no longer be managed from production areas promptly.
  - Train employees to rinse and sanitize waterproof boots when moving from infested to uninfested soil.
  - Rinse, then dunk tools in sanitizer solution when moving from infested soil to uninfested soil.
  - Control weeds to prevent vectors such as insects from harboring near crop plants.

Maples showing signs of stress in a field with poor drainage and nutsedge growing around the base of the trees.

Field production with clean roadways (free of weeds and debris) and good drainage.

WATER MANAGEMENT

Water-borne pathogens such as *Phytophthora* sp. can easily spread through a nursery via application of irrigation water or by the movement of irrigation water through the nursery (i.e. improper drainage). Here are some guidelines that can help mitigate production risks associated with water management.

Water Management

- Water Quality
- Drainage
- Irrigation