Smart & Economical Disease Management

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Ornamentals, Vegetables
Christmas trees
Disease Quadrangle

- Host
- Economics
- Environment
- Pathogen
- Man

Designed by Kelly Ivors
Pest Prevention/Management

• Critical Control Points
  - Disease exclusion
  - Cleaning / sanitation
    • Plant Debris Handling and Disposal
  - Proper diagnosis / scouting
  - Management of environment / moisture
  - Use most effective bio- and chemical- controls
BEST MANAGEMENT PRACTICES

- Best Management Practices (BMPs)

- Developed for *P. ramorum* ...

- But applicable to most diseases
Sanitation: tools, benches

- Bleach
- Quaternary ammonium
- Hydrogen peroxide
- Phenolics

source: Nursery Industry BMPs P. ramorum, CA
Reuse trays / pots?

Pest Prevention/Management

Section 1

Cleaning & Sanitation/Plant Debris Handling & Disposal

USE NEW OR CLEAN AND PROPERLY DISINFESTED POTS FOR HR PLANT PRODUCTION. REFERENCE USDA LIST OF APPROVED DISINFECTANT OPTIONS

source: Nursery Industry BMPs P. ramorum, CA
# Sanitation table

**K. Ivors and Mike Munster; NC State**

Treatments used for sanitizing tools, equipment, pots, flats, surfaces, and other related items.

All items should be free of organic debris before exposure to the treatments listed below.

<table>
<thead>
<tr>
<th>Material or Treatment</th>
<th>Trade name</th>
<th>Formulation</th>
<th>Remarks</th>
<th>Contact time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol, ethyl and isopropyl</td>
<td>Various commercial brands;</td>
<td>Depends on formulation. Read label.</td>
<td>Evaporates quickly so that adequate contact time may not be achieved; high concentrations of organic matter diminish effectiveness, flammable.</td>
<td>10 min for equipment, pots, flats and surfaces. Tools can be dipped for 10 seconds and allowed to dry. Do not rinse.</td>
</tr>
<tr>
<td>(grain, rubbing, wood) (70-100%)</td>
<td>Lysol Spray (also includes quaternary ammonium)</td>
<td>Typically full strength for RTU (Ready To Use) formulations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenolics</td>
<td>Pheno-Cen Spray Disinfectant</td>
<td>Depends on formulation. Read label.</td>
<td>Phenol penetrates latex gloves, eye/skin irritant; causing redness upon contact.</td>
<td>10 min for equipment, pots, flats and surfaces.</td>
</tr>
<tr>
<td>Peroxyacetic acid and hydrogen peroxide mixture</td>
<td>ZeroTol;</td>
<td>2.5 oz per gallon of water;</td>
<td>Corrosive; causes irreversible eye damage; eye/skin irritant. Low odor. Use according to label.</td>
<td>10-15 min</td>
</tr>
<tr>
<td></td>
<td>SaniDate;</td>
<td>Depends on formulation. Read label.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quaternary ammonium</td>
<td>Consan Triple Action 20;</td>
<td>Depends on formulation. Typically 1 tablespoon per gallon of water.</td>
<td>Effective for non-porous surface sanitation, e.g. floors, walls, benches, pots. Low odor, irritation. Use according to label.</td>
<td>10-15 min</td>
</tr>
<tr>
<td></td>
<td>Phynsan 20;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Greenshield 20;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium hypochlorite (5.25%)</td>
<td>Clorox;</td>
<td>10%; or a 1:9 ratio of bleach : water</td>
<td>Inactivated by organic matter; fresh solutions should be prepared every 8 hr or more frequently if exposed to sunlight, corrosive to metal; irritating to eyes and skin; Exposure to sunlight reduces efficacy. Keep solution in opaque container.</td>
<td>10-15 min for equipment, pots, flats and surfaces. Tools can be dipped for 10 seconds and allowed to dry. Do not rinse.</td>
</tr>
<tr>
<td></td>
<td>Commercial bleach;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam</td>
<td>NA</td>
<td>Cover or otherwise seal</td>
<td>For plastic pots and trays, heat center of steamer between 150°F – 160°F; For less heat-sensitive objects, heat to 180°F.</td>
<td>60 min; 20 min.</td>
</tr>
<tr>
<td>Solarization</td>
<td>NA</td>
<td>Place clean items on solid surface, cover tightly with CLEAR plastic.</td>
<td>Clear plastic works much better.</td>
<td>140°F, 4 to 8 hr/day for 7 days</td>
</tr>
</tbody>
</table>

[www.cals.ncsu.edu/plantpath/extension/clinic/](http://www.cals.ncsu.edu/plantpath/extension/clinic/)
Exclusion: disease free plants

Section I
Pest Prevention/Management

a
Exclusion of Pathogen

CONFIRM NURSERY STOCK IS PROPAGATED FROM MATERIALS OBTAINED ON SITE, OR THAT THE BUY-INS ARE RECEIVED FROM NURSERIES THAT ARE LICENSED AND/OR CERTIFIED ACCORDING TO ALL APPLICABLE PHYTOSANITARY LAWS AND REGULATIONS.

source: Nursery Industry BMPs P. ramorum, CA
Exclusion: Inspect buy-ins

Section 1: Pest Prevention/Management

Routine monitor incoming HAP (buy-ins, returns, transfers) for symptoms of P. ramorum.

source: Nursery Industry BMPs P. ramorum, CA
Exclusion: Commingling (bad idea)

Section 1
Pest Prevention/Management

a
Exclusion of Pathogen

Avoid commingling incoming hosts and associated plants (HAP) with existing stock.

Source: Nursery Industry BMPs P. ramorum, CA
Pre-treat stock plants

FOR PLANTS THAT ARE PRONE TO DISEASES, CHEMICALLY TREAT CROP IN THE FIELD PRIOR TO TAKING CUTTINGS, TAKE CUTTINGS ONLY FROM HEALTHY PLANTS AND DIP CUTTINGS IN AN APPROVED DISINFECTANT SOLUTION BEFORE STICKING.

source: Nursery Industry BMPs P. ramorum, CA
Get the right diagnosis

Know what your problem is...
and
What the symptoms look like
http://www.cals.ncsu.edu/plantpath/extension/clinic/

http://www.cals.ncsu.edu/plantpath/extension/clinic/video/
Inspect plants: Scouting

Section 1
Pest Prevention/Management

Inspection

25 BMP
INSPECT HR PLANTS MONTHLY THROUGHOUT THE GROWING SEASON. SEE SECTION II.

source: Nursery Industry BMPs P. ramorum, CA
Environmental Management

Pest Prevention/Management

Moisture Management

Avoid overhead irrigation of HR plants. Irrigate in a manner to avoid prolonged leaf wetness.

Source: Nursery Industry BMPs P. ramorum, CA
Fungicides should always be used in combination with cultural control

Very few fungicides have curative action;

Timing and rate of application are critical;

Pathogens may develop resistance to fungicides:

Mefenoxam resistance is prevalent... increasing in greenhouse industry
Adorn (fluopicolide); FRAC 43
Orvego (dimethomorph & ametoctradin); FRAC 40+45
Segway (cyazofamid); FRAC 21
FenStop (fenamidone); FRAC 11; No NL label
Disarm (fluoxastrobin); FRAC 11
Tourney (metconazole); FRAC 3; No GH label
Torque (tebuconazoloe); FRAC 3; No GH label
Palladium (cyprodinil & fludioxonil); FRAC 9 & 12; NO L
Regalia (extract Giant Knotweed).
>1,000 fungal species capable of producing leaf spots on herbaceous & woody ornamentals

Caused by species of Alternaria, Bipolaris, Cercospora, Entomosporium, Mycosphaerella, Phylllosticta, Septoria...

Can be round or angular; bleached out or brown, sometimes with a dark-colored border
**Fungal Leaf Spots**

- **M5: Chlorothalonil**
  - Daconil
  - Spectro (+ thiophanate methyl - FRAC 1)
  - GNL

- **M3: Mancozeb**
  - Dithane, Protect
  - GNL

- **11: Strobilurins**
  - Heritage; Insignia; Cygnus; Compass
  - GNL
  - FenStop
  - Pageant (+ boscalid - FRAC 7)
  - ONLY GH
  - GNL

- **3: DMIs**
  - Banner Maxx (propiconazole)
  - ONLY NL
  - TOURNEY (metconazole): New Valent product
  - ONLY NL
  - TORQUE (tebuconazole): New Cleary product
  - ONLY NL
POWDERY MILDEW

Commonly found on dogwood, Prunus, Gerbera daisy, hydrangea, rose, petunia;

Obligate biotrophs (requires living host);

Caused by species of Blumeria, Erysiphe, Leveillula, Microsphaera, Phyllactinia, Podosphaera, Sphaerotheca and Uncinula.
Powdery mildew
POWDERY MILDEW

5: Piperalin
Pipron; THE BEST ERRADICANT ONLY GH

M5: Chlorothalonil
Daconil; GNL
Spectro (+ thiophanate methyl- FRAC 1); GNL

M1: Fixed copper
Camelot; CuPro; Phyton 27; GNL

11: Strobilurins
Heritage; Insignia; Cygnus; Compass; GNL
FenStop; ONLY GH
Pageant (+ boscalid- FRAC 7); GNL

3: DMIs
Hoist/Eagle/Systhane (myclobutanil); GNL
Banner Maxx (propiconazole); ONLY NL
Tourney (metconazole); New Valent product ONLY NL
Torque (tebuconazole); New Cleary product ONLY NL

Sulfur
Biorationals
Rhapsody
Neem oil
BOTRYTIS: Gray mold

Wide host range in the GH; potted plants, bedding plants, foliage plants, cut flowers, hanging baskets, vegetable transplants

Weak pathogen; infects succulent tissue including flowers and fruit.

Management requires good sanitation.
Botrytis spores
BACTERIAL LEAF SPOTS

Caused by species of Pseudomonas, Xanthomonas, & Acidovorax

English Ivy very susceptible...

Spreads via splash and contaminated tools

Limited selection of bactericides available
Use PREVENTATIVELY; no more than 1X per week:

**M1**: Fixed copper
   - Camelot; CuPro; Phyton 27;  
   - Junction;  
   - Bacillus subtilis Cease (used to be Rhapsody);  
   - Streptomycin Agri-Mycin;  

**M1+M3**: Fixed copper + Mancozeb  
   - Junction;  

**NA**: Bacillus subtilis  
   - Cease (used to be Rhapsody);  

**25**: Streptomycin  
   - Agri-Mycin;
Phytophthora & Pythium root rots

Hundreds of ornamental plant species are susceptible. Can cause root rot, crown rot, and foliar blights.

Caused by a few dozen Phytophthora species in U.S. cinnamomi, nicotianae, drecshleri, cryptogea, citricola, citrophthora, cactorum, cambivora, foliorum, gonapodyides, heveae, hibernalis, palmivora, ramorum, syringae, tropicalis... plus many more.
Root rot
African violet
Phytophthora & Pythium management

• Rapid detection & removal of infected plants
• Well drained areas and substrates
• Irrigation water treatment (if using recycled water)
• Disinfectants for surfaces between crops
• Preventative fungicides - drenches & sprays
New Detection Technologies...

- *Phytophthora* ImmunoStrip
  www.agdia.com

5 min; $5.00

*Pythium* Lateral flow device
NEOGEN (Europe)
Increased use of Mefenoxam (and Aliette)

Comparative usage of major oomyceticides in the nursery and floriculture industry of the six program states (CA, FL, MI, PA, OR, TX) between 2000 and 2006 (http://www.nass.usda.gov/)
Mefenoxam resistance common in NC Phytophthora
Heather Olson's thesis 2010 (Mike Benson)

Table 1.2. Location, host of origin, and phenotypic characteristics of isolates of Phytophthora collected during 2007 and 2008 from floriculture crops in North Carolina.

<table>
<thead>
<tr>
<th>Group</th>
<th>Location</th>
<th>Host plant family</th>
<th>Host</th>
<th>Species</th>
<th>No. of isolates</th>
<th>Mating type</th>
<th>Mefenoxam sensitivity 1 µg a.i./ml</th>
<th>Mefenoxam sensitivity 100 µg a.i./ml</th>
<th>EC₅₀ (µg a.i./ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>Dusty miller</td>
<td>Asteraceae</td>
<td>P. nicotianae</td>
<td>26</td>
<td>A1</td>
<td>Resistant</td>
<td>Resistant</td>
<td>415</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>Gerbera daisy</td>
<td>Asteraceae</td>
<td>P. nicotianae</td>
<td>2</td>
<td>A1</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>NA</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>Petunia</td>
<td>Solanaceae</td>
<td>P. nicotianae</td>
<td>9</td>
<td>A1</td>
<td>Resistant</td>
<td>Resistant</td>
<td>353</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>Petunia</td>
<td>Solanaceae</td>
<td>P. nicotianae</td>
<td>9</td>
<td>A1</td>
<td>Resistant</td>
<td>Resistant</td>
<td>429</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>Calibrachoa</td>
<td>Solanaceae</td>
<td>P. nicotianae</td>
<td>8</td>
<td>A1</td>
<td>Resistant</td>
<td>Resistant</td>
<td>427</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>Gardenia</td>
<td>Rubiaceae</td>
<td>P. nicotianae</td>
<td>7</td>
<td>A2</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>NA</td>
</tr>
<tr>
<td>7</td>
<td>G</td>
<td>Fuchsia</td>
<td>Onagraceae</td>
<td>P. nicotianae</td>
<td>4</td>
<td>A1</td>
<td>Resistant</td>
<td>Resistant</td>
<td>363</td>
</tr>
<tr>
<td>8</td>
<td>G</td>
<td>Annual vinca</td>
<td>Apocynaceae</td>
<td>P. nicotianae</td>
<td>1</td>
<td>A2</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>363</td>
</tr>
<tr>
<td>9</td>
<td>H</td>
<td>Cushion spurge</td>
<td>Euphorbiaceae</td>
<td>P. nicotianae</td>
<td>10</td>
<td>A1</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>NA</td>
</tr>
<tr>
<td>10</td>
<td>H</td>
<td>Verbena</td>
<td>Verbenaceae</td>
<td>P. nicotianae</td>
<td>9</td>
<td>A2</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>NA</td>
</tr>
<tr>
<td>11</td>
<td>I</td>
<td>Gerbera daisy</td>
<td>Asteraceae</td>
<td>P. nicotianae</td>
<td>1</td>
<td>A2</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>NA</td>
</tr>
<tr>
<td>12</td>
<td>I</td>
<td>Verbena</td>
<td>Verbenaceae</td>
<td>P. nicotianae</td>
<td>1</td>
<td>A2</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>NA</td>
</tr>
<tr>
<td>13</td>
<td>K</td>
<td>Calibrachoa</td>
<td>Solanaceae</td>
<td>P. nicotianae</td>
<td>10</td>
<td>A1</td>
<td>Resistant</td>
<td>Intermediate</td>
<td>247</td>
</tr>
<tr>
<td>14</td>
<td>B</td>
<td>Gerbera daisy</td>
<td>Asteraceae</td>
<td>P. drehshleri</td>
<td>29</td>
<td>A1</td>
<td>Resistant</td>
<td>Resistant</td>
<td>341</td>
</tr>
<tr>
<td>15</td>
<td>G</td>
<td>Gerbera daisy</td>
<td>Asteraceae</td>
<td>P. drehshleri</td>
<td>3</td>
<td>A1</td>
<td>Resistant</td>
<td>Resistant</td>
<td>727</td>
</tr>
<tr>
<td>16</td>
<td>G</td>
<td>Euphycia</td>
<td>Onagraceae</td>
<td>P. drehshleri</td>
<td>3</td>
<td>A1</td>
<td>Resistant</td>
<td>Resistant</td>
<td>910</td>
</tr>
<tr>
<td>17</td>
<td>G</td>
<td>Gerbera daisy</td>
<td>Asteraceae</td>
<td>P. drehshleri</td>
<td>1</td>
<td>A1</td>
<td>Resistant</td>
<td>Resistant</td>
<td>755</td>
</tr>
<tr>
<td>18</td>
<td>B</td>
<td>Gerbera daisy</td>
<td>Asteraceae</td>
<td>P. cryptogea</td>
<td>2</td>
<td>A1</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>NA</td>
</tr>
<tr>
<td>19</td>
<td>C</td>
<td>Blue daze</td>
<td>Convolvulaceae</td>
<td>P. cryptogea</td>
<td>1</td>
<td>A2</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>NA</td>
</tr>
<tr>
<td>20</td>
<td>E</td>
<td>Gerbera daisy</td>
<td>Asteraceae</td>
<td>P. cryptogea</td>
<td>2</td>
<td>A2</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>NA</td>
</tr>
<tr>
<td>21</td>
<td>I</td>
<td>Verbena</td>
<td>Verbenaceae</td>
<td>P. cryptogea</td>
<td>1</td>
<td>A1</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>NA</td>
</tr>
<tr>
<td>22</td>
<td>J</td>
<td>Dusty miller</td>
<td>Asteraceae</td>
<td>P. cryptogea</td>
<td>10</td>
<td>A2</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>NA</td>
</tr>
<tr>
<td>23</td>
<td>B</td>
<td>Gloxinia</td>
<td>Gesneriaceae</td>
<td>P. tropicalis</td>
<td>2</td>
<td>A2</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>NA</td>
</tr>
</tbody>
</table>

- Overall 65% of isolates were insensitive at 1 ppm
<table>
<thead>
<tr>
<th>Product Code</th>
<th>Product Name</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>43.</td>
<td>Fluopicolide</td>
<td>Adorn; (poinsettias off label)</td>
<td>GNL</td>
</tr>
<tr>
<td>21.</td>
<td>Cyazofamid</td>
<td>Segway;</td>
<td>GNL</td>
</tr>
<tr>
<td>11.</td>
<td>Fenamidone</td>
<td>FenStop;</td>
<td>ONLY GH</td>
</tr>
<tr>
<td>14.</td>
<td>Etridazole</td>
<td>Terrazole; Truban;</td>
<td>GNL</td>
</tr>
<tr>
<td>4.</td>
<td>Mefenoxyan</td>
<td>Subdue Maxx;</td>
<td>GNL</td>
</tr>
<tr>
<td>40.</td>
<td>Dimethomorph</td>
<td>Stature; (formulation change to SC)</td>
<td>GN</td>
</tr>
<tr>
<td>40+45.</td>
<td>Dimethomorph + ametoctradin</td>
<td>Orvego [BASF]</td>
<td>1 year until registration</td>
</tr>
</tbody>
</table>
DOWNY MILDEWS

Caused by numerous species of Oomycetes; Basidiophora, Bremia, Peronospora, Plasmopara, Pseudoperonospora, Sclerospora ...

Alyssum, Aster, Buddleia, Coreopsis, Dusty miller, Gaillardia, Gazania, Geranium, Geum, Iberis, Lamium, Rose basil, begonia, blue daze, Calibrachoa, Dusty miller, Easter lily, Euphorbia, Fuchsia, Gerber daisy, ivy (Hedera spp), million bells, nandina, petunia, verbena
DOWNY MILDEW

- Extremely weather dependent
- Favored by cool, wet weather (50-70 F)
  - Develops rapidly
- Rainy periods: greenhouse crops at risk

Keep leaf wetness to a minimum;
Keep humidity down; ≤3 hours above 85% RH;
Leaf drop is common; do not let fallen leaves accumulate
Atmospheric Transport of Spores

Distance (1-5,000 km)

Atmospheric boundary layer

Height 1-3,000 meters

SOURCE

Ascent

Transport

Deposition

Sedimentation

Rainout & Washout

Target

Ground Level
Peronospora belbaharii
downy mildew of coleus
43. Fluopicolide
   Adorn, (poinsettias off label)  GNL

21. Cyazofamid
   Segway;  GNL

11. Fenamidone
   FenStop;  ONLY GH

14. Etridazole
   Terrazole; Truban;  GNL

4. Mefenoxam
   Subdue Maxx;  GNL

40. Dimethomorph
   Stature, (formulation change to SC)  GN

40+45. Dimethomorph + ametoctradin
   Orvego [BASF]  1 year until registration
Inoculum (pathogen) sources?
Capturing run-off
Capturing run-off
Capturing run-off
Why sanitize water?

Algae control in ponds / lines / emitters

Reduced fungicide/algaecide costs later

Control Phytophthora and Pythium

NOT NECESSARY TO SANITIZE WELL WATER FOR PATHOGENS

Odor Control
Water treatment options...

- Chlorination (gas, tablets, or liquid)
- Copper ionization
- Ozone
- UV
- Commercial peroxidases / copper
- Slow sand filtration
- Pond design
UV radiation

Historically done to kill plant pathogens (254 nm)

Disinfection a function of duration and intensity

Turbidity (clarity) of water impacts effectiveness

Often coupled with ozone

$25,000 plus filters, etc
Copper ionization
Hydrogen peroxide

Strong oxidizer; Breaks down readily;
ZeroTol / SaniDate commercial formulation
Commercial peroxidases: larger greenhouses
Flood floors
Lowers pH substantially
Most practical and cost effective approach:
Continuous chlorination set to deliver 2 ppm free chlorine at the sprinklers

“free chlorine” ≤ 2.9 ppm conc is generally considered safe for most woody crops (must be low in turbidity)

3 forms of chlorine:
- Gas ($\text{Cl}_2$)
- Liquid (sodium hypochlorite)
- Solid (calcium hypochlorite)

Maximizing distance in the catch basin between return water entrance and intake to the pump will decrease inoculum
Calcium hypochlorite (solid form of chlorine)

Chlorine tablet: Accu-Tab

Nursery / woody plants tolerant
Chlorine gas: Regal

Regal Gas Chlorinator

CHLORINATOR CLAMPS DIRECTLY ON CYLINDER VALVE
VACUUM LINE
IF BREAK OCCURS, CHLORINE STOPS
DIFFUSER
GAS CHLORINE
WATER SUPPLY
EJECTOR