

Smart & Economical Disease Management

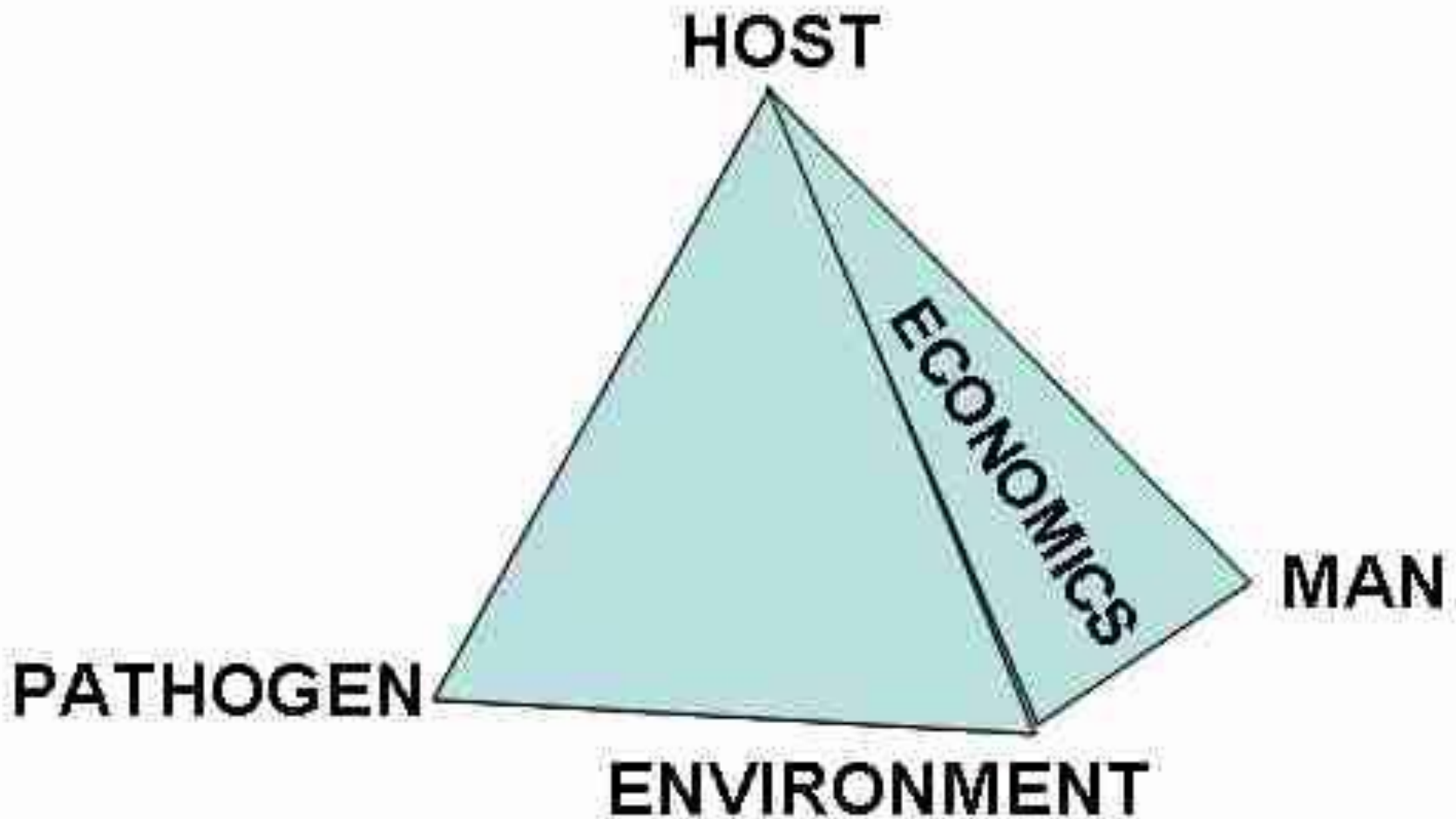
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Ornamentals, Vegetables
Christmas trees



NORTH CAROLINA STATE UNIVERSITY
MOUNTAIN HORTICULTURAL CROPS
RESEARCH AND EXTENSION CENTER

Disease Quadrangle



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



Nursery Industry
BEST MANAGEMENT PRACTICES
for *Phytophthora ramorum*
- to prevent the introduction or establishment
in California nursery operations
Version 1.0

CONTRIBUTORS
CA Association of Nurseries and Garden Centers
Nursery Growers Association
CA Farm Bureau
San Diego Flower and Plant Association
Garden Flow Council
CA Oak Mortality Task Force
California Center for Urban Horticulture, UC Davis
Horticultural Research Institute

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COVER PHOTO
Brigg Nursery in Goleta, CA.
ERIC LARSON, photographer



Sanitation: tools, benches

- Bleach
- Quaternary ammonium
- Hydrogen peroxide
- Phenolics

Pest Prevention/Management Section I

Cleaning & Sanitation/Plant Debris Handling & Disposal

d



AFTER EVERY CROP ROTATION, DISINFECT PROPAGATION MIST BEDS, SORTING AREAS, CUTTING BENCHES, MACHINES AND TOOLS TO MINIMIZE THE SPREAD OR INTRODUCTION OF PATHOGENS. REFERENCE USDA LIST OF APPROVED DISINFECTANT OPTIONS²

BMP 16

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ATED	SERY	N/A

Reuse trays / pots?

Pest Prevention/Management

Section I

Cleaning & Sanitation/Plant Debris Handling & Disposal

d



**USE NEW OR CLEAN AND PROPERLY DISINFESTED
POTS FOR HR PLANT PRODUCTION. REFERENCE
USDA LIST OF APPROVED DISINFECTANT OPTIONS²**



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.

Material or Treatment	Trade name	Formulation	Remarks	Contact time
Alcohol, ethyl and isopropyl (grain, rubbing, wood) (70-100%)	Various commercial brands; Lysol Spray (also includes quaternary ammonium)	Depends on formulation. Read label. Typically full strength for RTU (Ready To Use) formulations.	Evaporates quickly so that adequate contact time may not be achieved; high concentrations of organic matter diminish effectiveness; flammable.	10 min for equipment, pots, flats and surfaces. Tools can be dipped for 10 seconds and allowed to dry. Do not rinse.
Phenolics	Pheno-Cen Spray Disinfectant	Depends on formulation. Read label. Typically full	Phenol penetrates latex gloves; eye/skin irritant; remains active upon contact	10 min for equipment, pots, flats and surfaces

www.cals.ncsu.edu/plantpath/extension/clinic/

Peroxyacetic acid and hydrogen peroxide mixture	ZeroTol; SaniDate;	2.5 oz per gallon of water; Depends on formulation. Read label.	Corrosive; causes irreversible eye damage; eye/skin irritant. Low odor. Use according to label.	10-15 min
Quaternary ammonium	Consan Triple Action 20; Physan 20; GreenShield 20;	Depends on formulation. Typically 1 tablespoon per gallon of water.	Effective for non-porous surface sanitation, e.g. floors, walls, benches, pots. Low odor, irritation. Use according to label.	10-15 min
Sodium hypochlorite (5.25%)	Clorox; Commercial bleach;	10%; or a 1:9 ratio of bleach : water	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.	10-15 min for equipment, pots, flats and surfaces. Tools can be dipped for 10 seconds and allowed to dry. Do not rinse.
Steam	NA	Cover or otherwise seal	For plastic pots and trays, heat center of steamer between 150°F – 160°F; For less heat-sensitive objects, heat to 180°F.	60 min; 20 min.
Solarization	NA	Place clean items on solid surface, cover tightly with CLEAR plastic.	Clear plastic works much better.	140°F, 4 to 8 hr/day for 7 days

Exclusion: disease free plants

Section I Pest Prevention/Management

a Exclusion of Pathogen



1
BMP

TED
ERY
N/A

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.

Exclusion: Inspect buy-ins

Section I Pest Prevention/Management

f Inspection



27
BMP

**ROUTINELY MONITOR INCOMING HAP
(BUY-INS, RETURNS, TRANSFERS) FOR
SYMPTOMS OF *P. RAMORUM*.**

Exclusion: Commingling (bad idea)

Section I Pest Prevention/Management

a Exclusion of Pathogen



3
BMP

AVOID COMMINGLING INCOMING HOSTS AND ASSOCIATED PLANTS (HAP) WITH EXISTING STOCK.

Pre-treat stock plants

Pest Prevention/Management

Section I

Cleaning & Sanitation/Plant Debris
Handling & Disposal

d

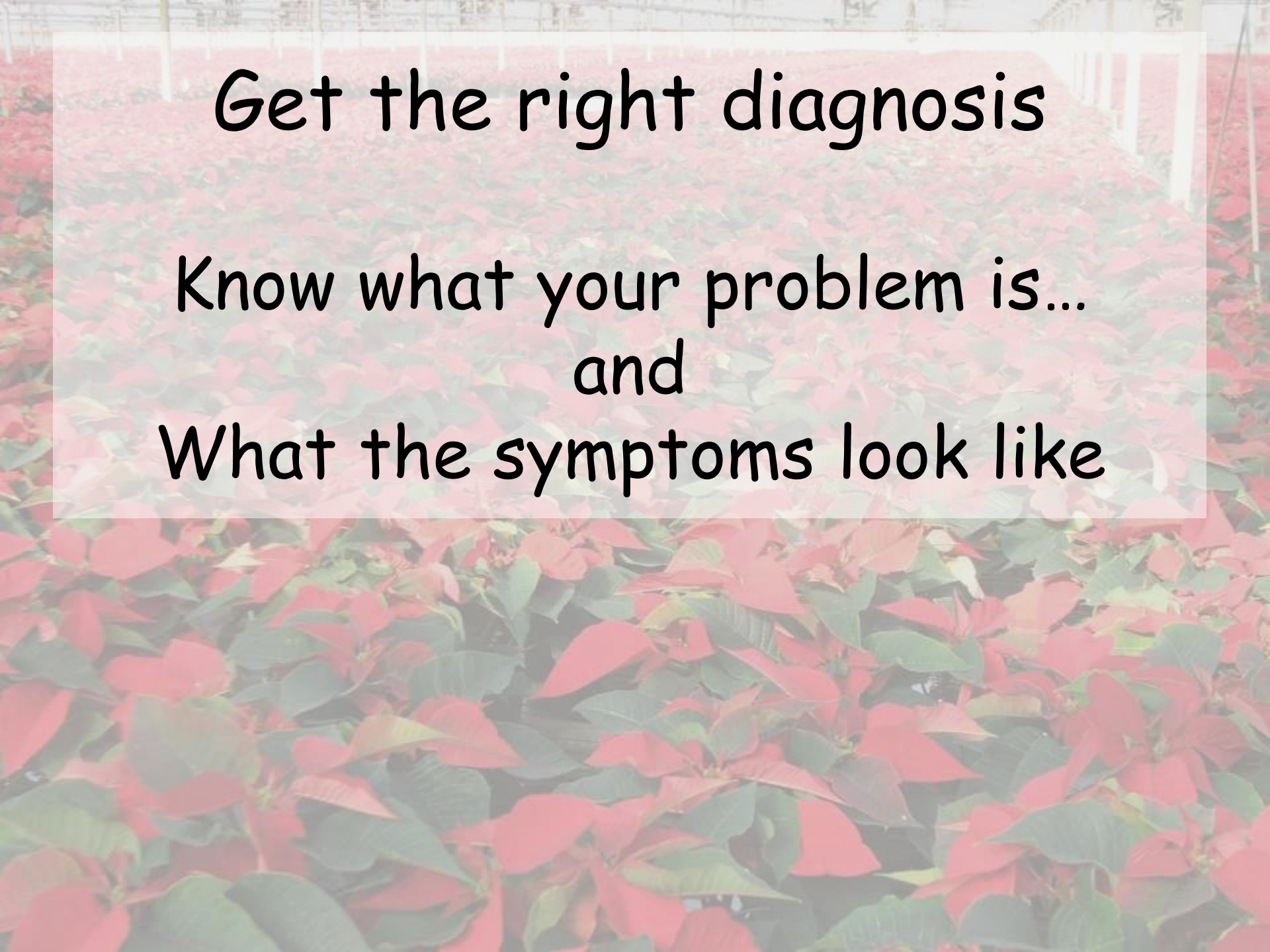


**FOR PLANTS THAT ARE PRONE TO DISEASES,
CHEMICALLY TREAT CROP IN THE FIELD PRIOR
TO TAKING CUTTINGS, TAKE CUTTINGS ONLY
FROM HEALTHY PLANTS AND DIP CUTTINGS IN
AN APPROVED DISINFECTANT SOLUTION
BEFORE STICKING.**

BMP 20



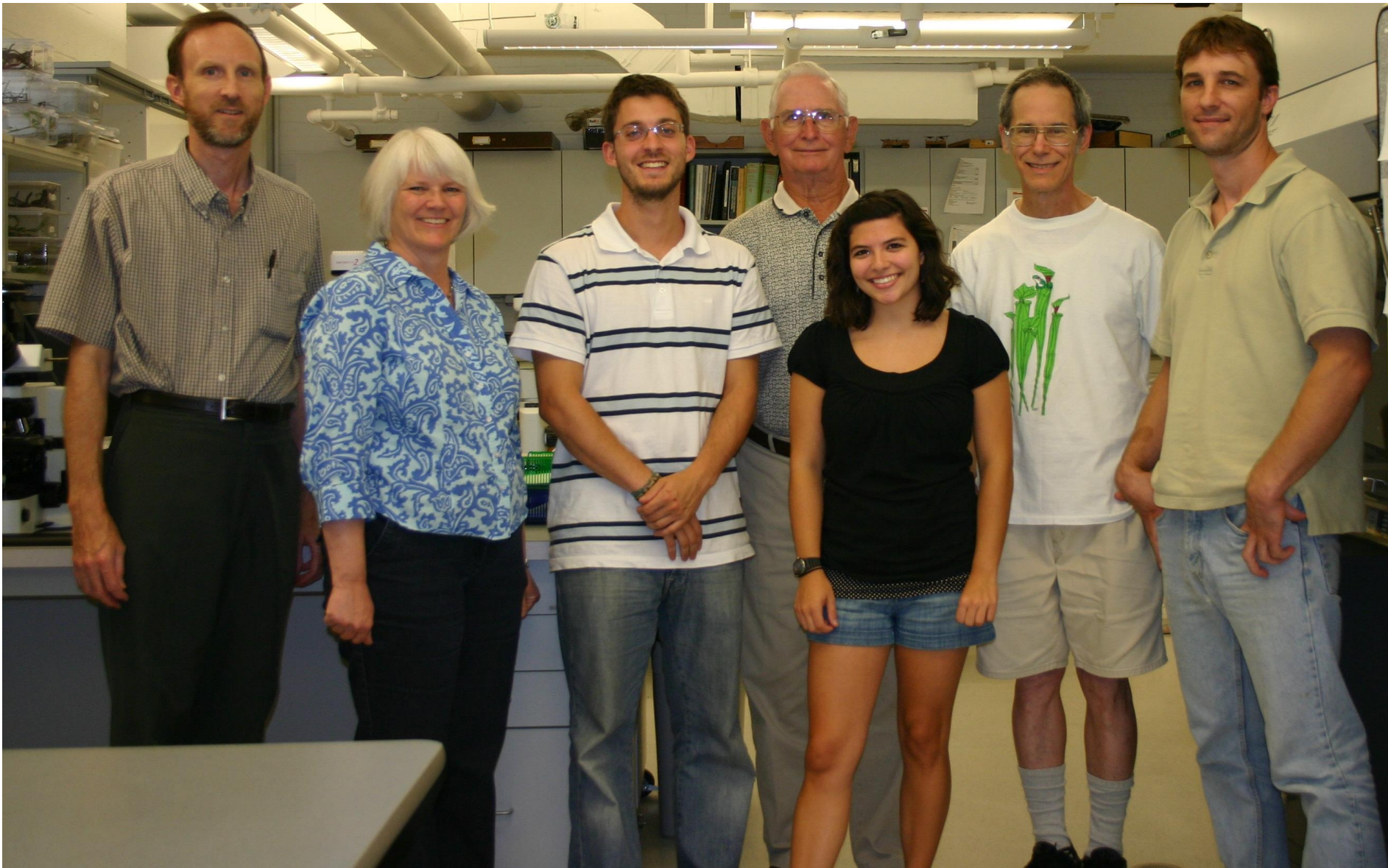
COMPLETED
BY
DATE



Get the right diagnosis

Know what your problem is...
and
What the symptoms look like

Plant Disease & Insect Clinic



<http://www.cals.ncsu.edu/plantpath/extension/clinic/>

<http://www.cals.ncsu.edu/plantpath/extension/clinic/>

<http://www.cals.ncsu.edu/plantpath/extension/clinic/video/>

The screenshot shows a web browser window displaying the NC State University Plant Disease and Insect Clinic website. The browser's address bar shows the URL <http://www.cals.ncsu.edu/plantpath/extension/clinic/>. The website header features the NC State University logo, the text "College of Agriculture and Life Sciences", and "Extension". Below this is the "DEPARTMENT OF PLANT PATHOLOGY" and a search bar with a "See Map" link.

The main content area is titled "Plant Disease and Insect Clinic". It includes a navigation menu on the left with options: HOME, ACADEMICS, EXTENSION, RESEARCH, PEOPLE, SEMINARS, ACTIVITIES, and CALENDAR. The "EXTENSION" menu item is highlighted, and a sub-menu is visible listing various resources such as "Extension Faculty", "Agricultural Crops, Ornamentals and Turfgrasses in North Carolina", "Plant Disease and Insect Clinic", "Plant Disease Information Notes", "North American Plant Disease Forecast Center", "NC Agricultural Chemicals Manual", "NC Pest News", "NC Cooperative Extension Service", and "NC Department of Agriculture Statistics".

The main content area features a banner image of a green tractor in a field. Below the banner, there is a section titled "Plant Disease and Insect Clinic" with a sub-header "North Carolina State University College of Agriculture and Life Sciences". This section includes four small images showing plant diseases: a leaf with brown spots, a close-up of a plant stem with a lesion, a leaf with a white powdery coating, and a close-up of a plant stem with a dark, sunken lesion.

The text below the images states: "The Plant Disease and Insect Clinic at NC State University provides disease diagnostic and insect identification services to help you grow healthy plants and crops. Extension specialists from Plant Pathology, Entomology, Horticulture, Crop Science and Soil Science diagnose problems on the samples received."

There are four bullet points with links: [Sample Submission and Fees](#), [Contact Points and Location](#), [Turfgrass Diagnostics](#), and [Virtual Clinic Tour](#).

The "Hours" are listed as "8 AM to 4:30 PM, Monday through Friday." The "Clinic Director" is identified as [Dr. Lane Tredway](#).

The "Contact Information" section provides phone numbers: "Disease problems: 919.515.3619" and "Insect related: 919.515.9530".

There are two more bullet points with links: [Access new electronic database](#) and [User instructions](#). The "User instructions" link has a sub-link: [Cooperative Extension Service and NCSU Users](#).

Inspect plants: Scouting

Section I Pest Prevention/Management

f Inspection



25 BMP

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

Environmental Management

Pest Prevention/Management

Section I

Moisture Management

b



**AVOID OVERHEAD IRRIGATION OF HR PLANTS.
IRRIGATE IN A MANNER TO AVOID PROLONGED
LEAF WETNESS.**

BMP 8

**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

New Fungicides and Modes of Action

Adorn (fluopicolide); FRAC 43

Orvegó (dimethomorph & ametoctradin); FRAC 40+45
1 yr away

Segway (cyazofamid); FRAC 21

FenStop (fenamidone); FRAC 11; **No NL label**

Disarm (fluoxastrobin); FRAC 11

Tourney (metconazole); FRAC 3; **No GH label**

Torque (tebuconazole); FRAC 3; **No GH label**

Palladium (cyprodinil & fludioxonil); FRAC 9 & 12; **NO L**

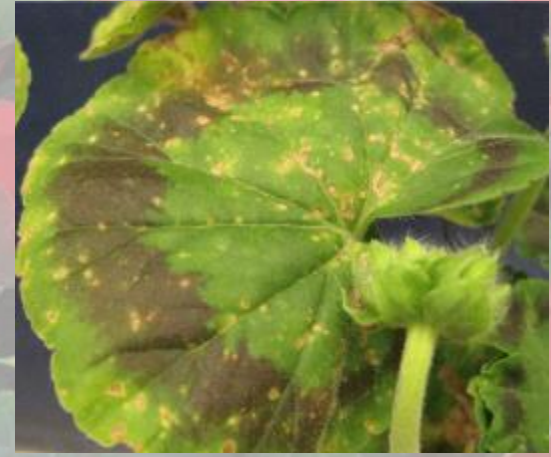
Regalia (extract Giant Knotweed).

FUNGAL LEAF SPOTS

>1,000 fungal species capable of producing leaf spots on herbaceous & woody ornamentals

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

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



FUNGAL LEAF SPOTS

FRAC #

→ M5: Chlorothalonil

Daconil; GNL

Spectro(+ thiophanate methyl- FRAC 1); GNL

M3: Mancozeb

Dithane, Protect; GNL

11: Strobilurins

Heritage; Insignia; Cygnus; Compass; GNL

FenStop; ONLY GH

Pageant (+ boscalid- FRAC 7) ; 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);

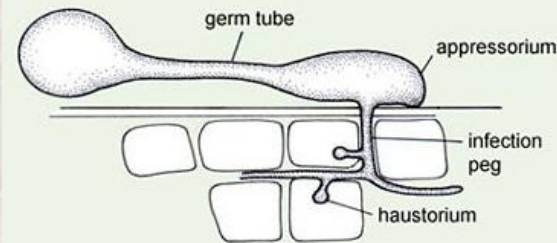
New Valent product

ONLY NL

Torque (tebuconazole);

New Cleary product

ONLY NL



Sulfur

Biorationals

Rhapsody

Neem oi

BOTRYTIS: Gray mold

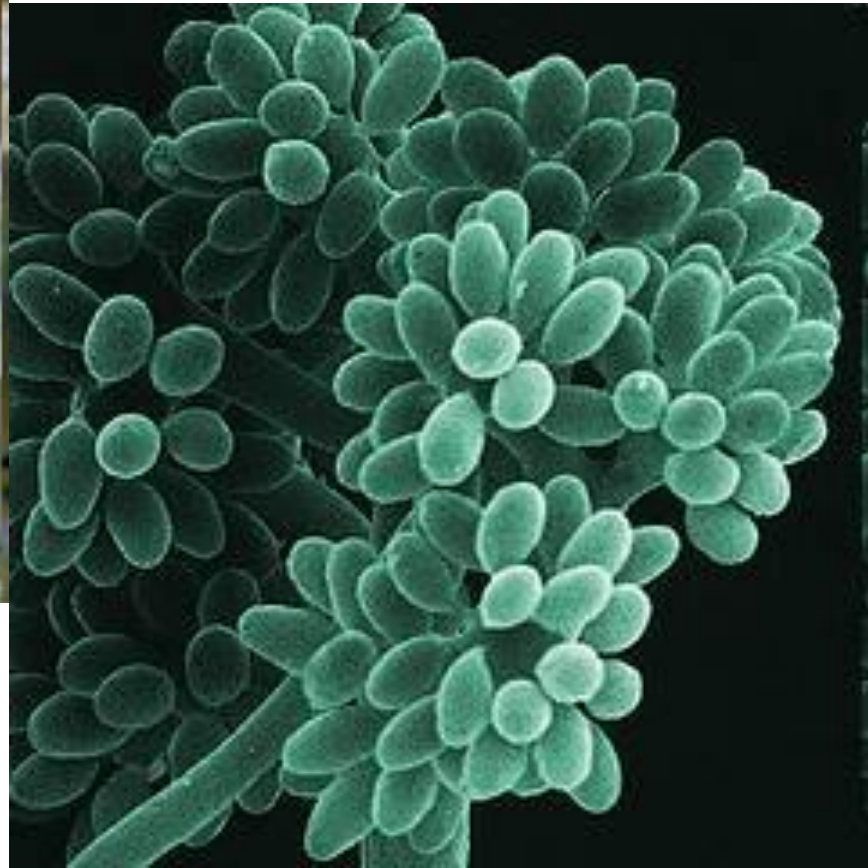
Wide host range in the GH; potted plants, bedding plants, foliage plants, cut flowers, hanging baskets, vegetable transplants

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



BACTERIAL LEAF SPOTS

Use PREVENTATIVELY; no more than 1X per week:

FRAC #

↓ M1: Fixed copper Camelot; CuPro; Phyton 27;	GNL
M1+M3: Fixed copper + Mancozeb Junction;	GNL
NA: <i>Bacillus subtilis</i> Cease (used to be Rhapsody);	GNL
25: Streptomycin Agri-Mycin;	ONLY NL

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*, *drechsleri*, *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...

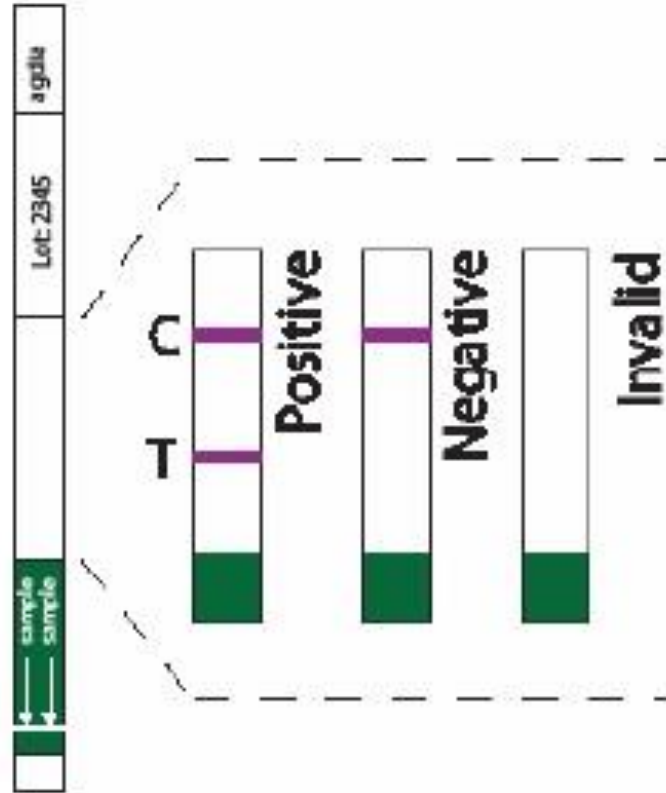


Leading the way to healthy crops.

-*Phytophthora* ImmunoStrip
www.agdia.com



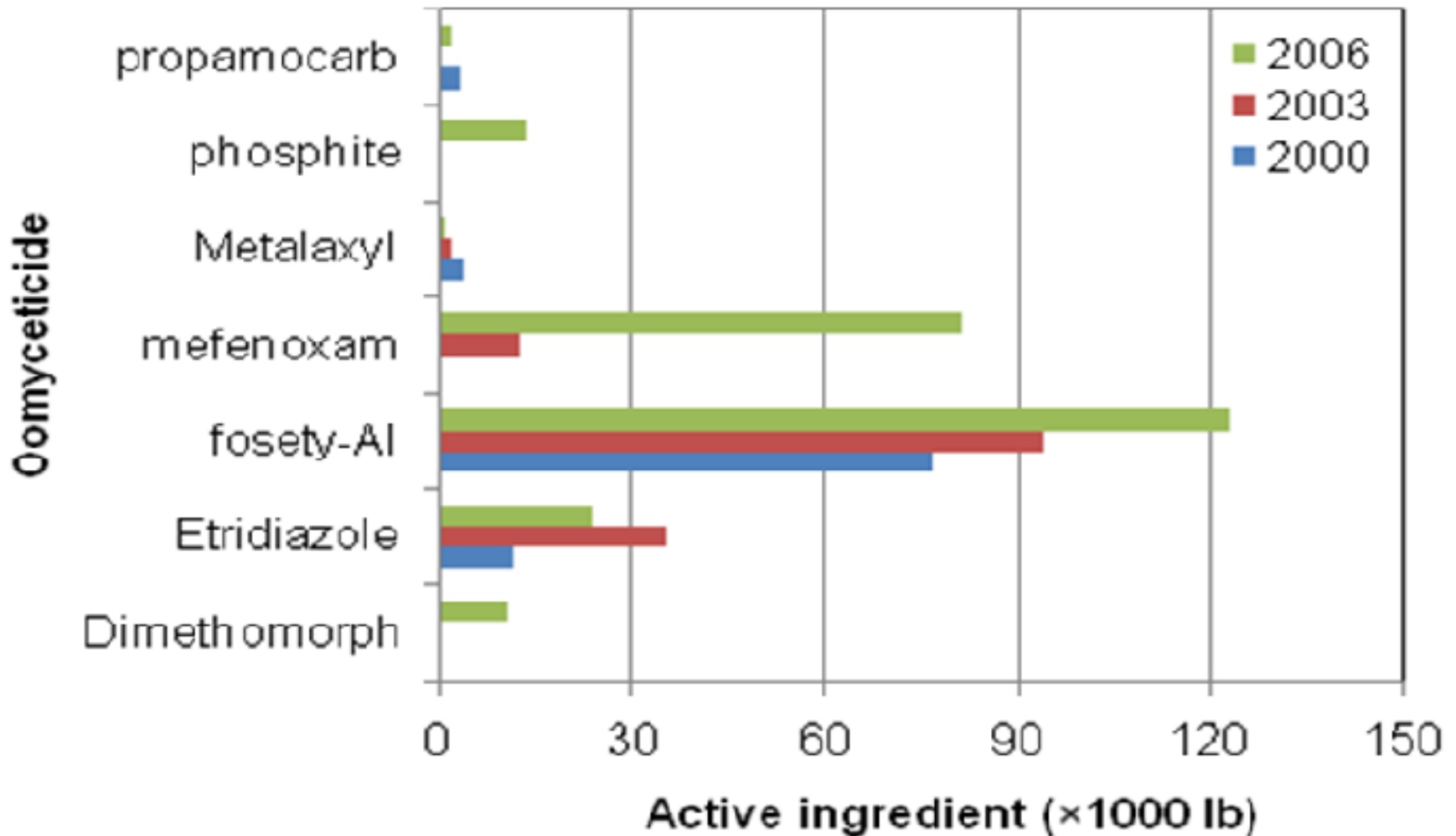
5 min; \$5.00



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.

Group ^b	Location	Host	Host plant family	Species	No. of isolates	Mating type	Mefenoxam sensitivity ^a		EC ₅₀ ^c ($\mu\text{g a.i./ml}$)
							1 $\mu\text{g a.i./ml}$	100 $\mu\text{g a.i./ml}$	
1	A	Dusty miller	Asteraceae	<i>P. nicotianae</i>	26	A1	Resistant	Resistant	415
2	A	Gerbera daisy	Asteraceae	<i>P. nicotianae</i>	2	A1	Sensitive	Sensitive	NA
3	F	Petunia	Solanaceae	<i>P. nicotianae</i>	9	A1	Resistant	Resistant	353
4	F	Petunia	Solanaceae	<i>P. nicotianae</i>	9	A1	Resistant	Resistant	429
5	F	Calibrachoa	Solanaceae	<i>P. nicotianae</i>	8	A1	Resistant	Resistant	427
6	F	Gardenia	Rubiaceae	<i>P. nicotianae</i>	7	A2	Sensitive	Sensitive	NA
7	G	Fuchsia	Onagraceae	<i>P. nicotianae</i>	4	A1	Resistant	Resistant	363
8	G	Annual vinca	Apocynaceae	<i>P. nicotianae</i>	1	A2	Sensitive	Sensitive	NA
9	H	Cushion spurge	Euphorbiaceae	<i>P. nicotianae</i>	10	A1	Sensitive	Sensitive	NA
10	H	Verbena	Verbenaceae	<i>P. nicotianae</i>	9	A2	Sensitive	Sensitive	NA
11	I	Gerbera daisy	Asteraceae	<i>P. nicotianae</i>	1	A2	Sensitive	Sensitive	NA
12	I	Verbena	Verbenaceae	<i>P. nicotianae</i>	1	A2	Sensitive	Sensitive	NA
13	K	Calibrachoa	Solanaceae	<i>P. nicotianae</i>	10	A1	Resistant	Intermediate	247
14	B	Gerbera daisy	Asteraceae	<i>P. drechsleri</i>	29	A1	Resistant	Resistant	341
15	G	Gerbera daisy	Asteraceae	<i>P. drechsleri</i>	3	A1	Resistant	Resistant	727
16	G	Fuchsia	Onagraceae	<i>P. drechsleri</i>	3	A1	Resistant	Resistant	910
17	G	Gerbera daisy	Asteraceae	<i>P. drechsleri</i>	1	A1	Resistant	Resistant	755
18	B	Gerbera daisy	Asteraceae	<i>P. cryptogea</i>	2	A1	Sensitive	Sensitive	NA
19	C	Blue daze	Convolvulaceae	<i>P. cryptogea</i>	1	A2	Sensitive	Sensitive	NA
20	E	Gerbera daisy	Asteraceae	<i>P. cryptogea</i>	2	A2	Sensitive	Sensitive	NA
21	I	Verbena	Verbenaceae	<i>P. cryptogea</i>	1	A1	Sensitive	Sensitive	NA
22	J	Dusty miller	Asteraceae	<i>P. cryptogea</i>	10	A2	Sensitive	Sensitive	NA
23	B	Gloxinia	Gesneriaceae	<i>P. tropicalis</i>	2	A2	Sensitive	Sensitive	NA

- Overall 65% of isolates were insensitive at 1 ppm

PHYTOPHTHORA ROOT ROT & DIEBACK

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

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

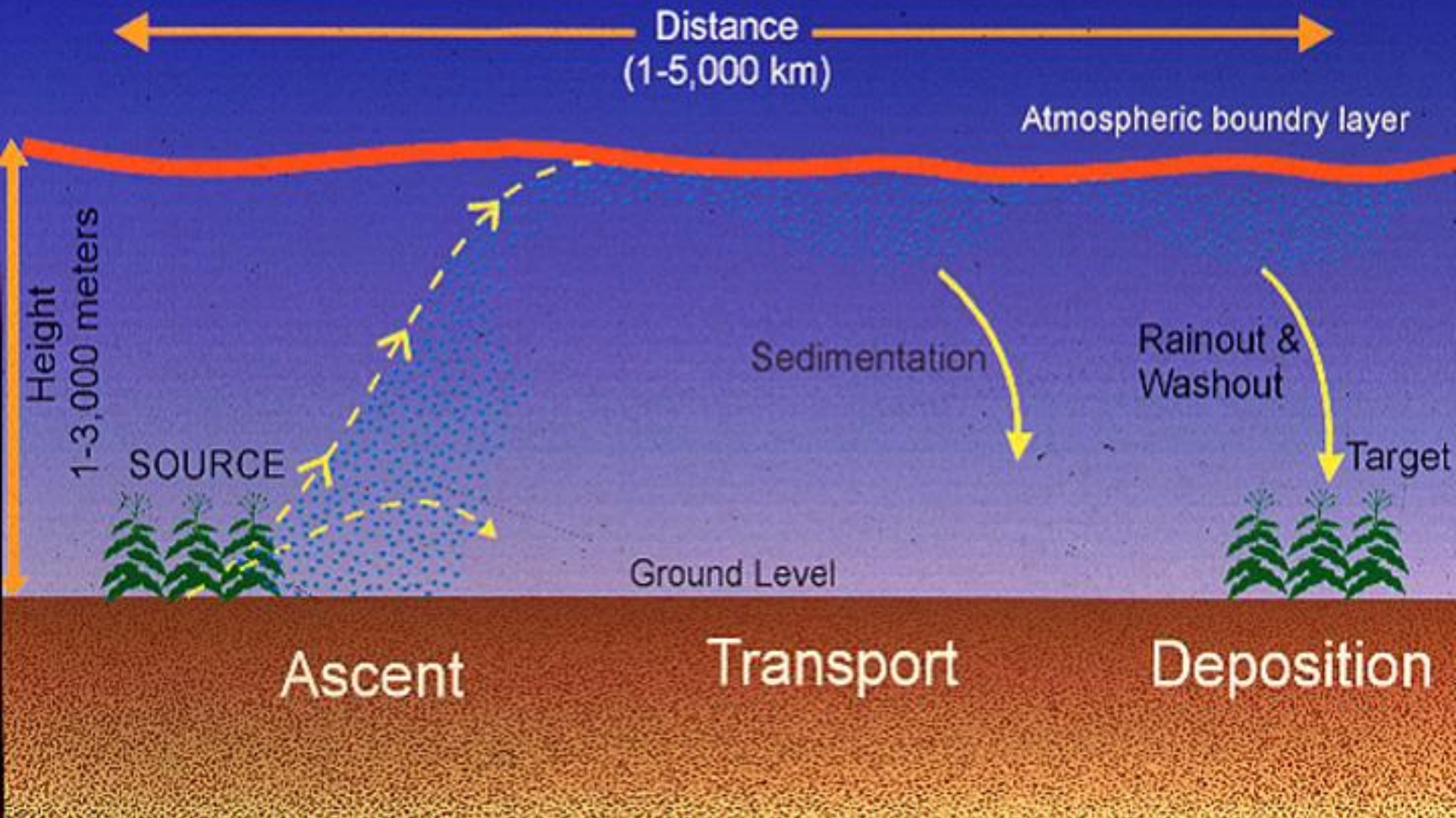
- Extremely weather dependent
- Favored by cool, wet weather (50-70 F)
 - Develops rapidly
- Rainy periods: greenhouse crops at risk

Keep leaf wetness to a minimum;

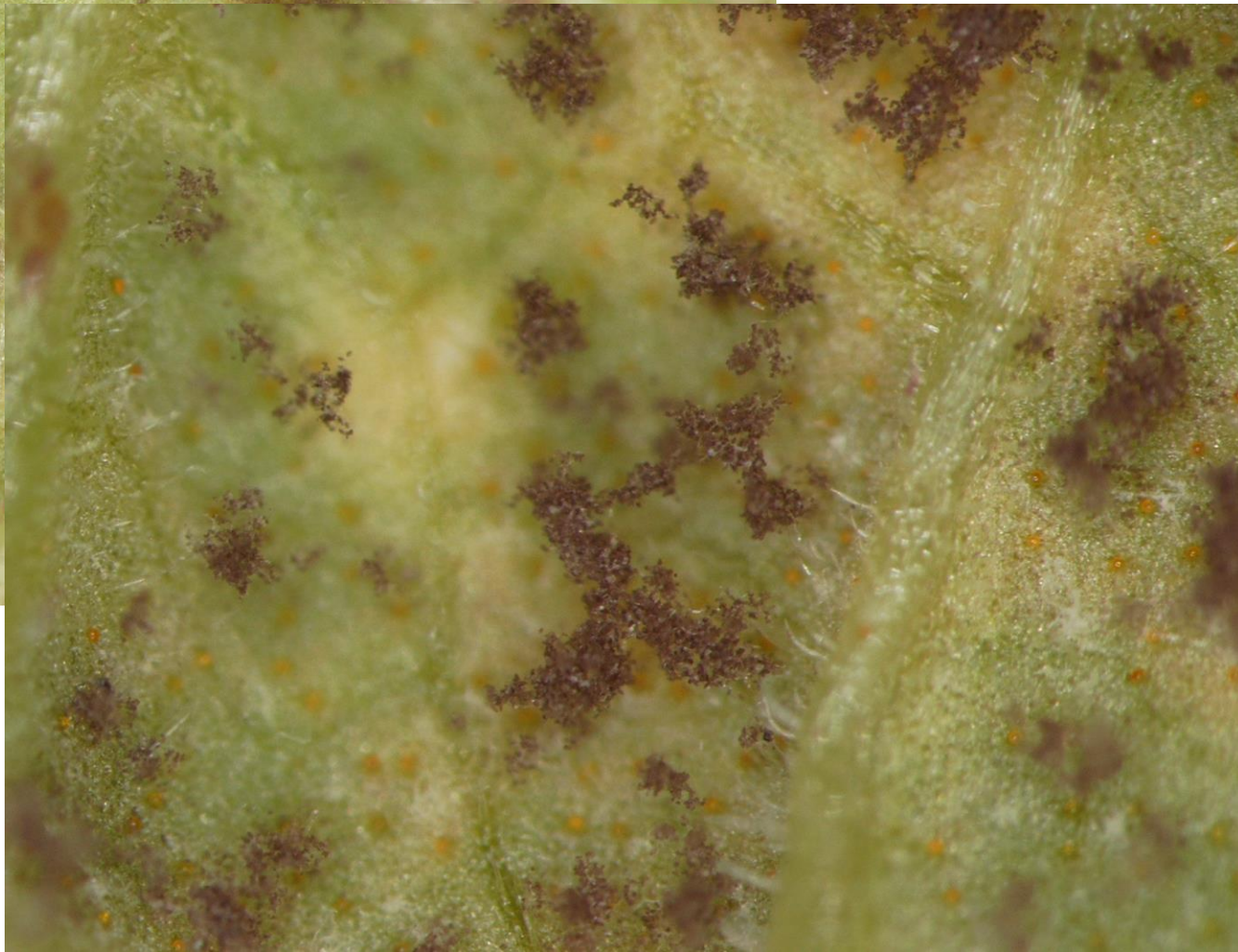
Keep humidity down; ≤ 3 hours above 85% RH;

Leaf drop is common; do not let fallen leaves accumulate

Atmospheric Transport of Spores



Peronospora belbaharii
downy mildew of coleus



DOWNY MILDEWS

43. Fluopicolide

Adorn, (poinsettias off label)

GNL

21. Cyazofamid

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Subdue Maxx;

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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



XEROTON³

**Algaecide,
Bactericide
& Fungicide**

For Control of Plant Pathogens

ACTIVE INGREDIENT

Hydrogen Peroxide.....	6.9%
Peroxyacetic Acid.....	4.4%
Octanoic Acid.....	3.3%
INERT INGREDIENTS.....	85.4%
Total.....	100.00%

KEEP OUT OF REACH OF CHILDREN
DANGER PELIGRO

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand the label, find someone to explain it to you in detail.)

U.S. Pat. Nos. 6,165,483;
6,024,986; 6,238,685
E.P.A. REG. NO. 49538-4
E.P.A. EST. NO. 60156-IL-1 (SI),
1677-IL-2 (J), 1677-MN-1 (P),
70271-CA-2 (C)

CONTENTS: 96 fluid ounces



Phyton Corporation
5608 International Parkway
New Hope, MN 55428
1-800-356-8733
www.phytoncorp.com







For nurseries

Economics, operation, reliability in effectiveness

Most practical and cost effective approach:

Continuous chlorination set to deliver 2 ppm free chlorine at the sprinklers

"free chlorine" \leq 2.9 ppm conc is generally considered safe for most woody crops (must be low in turbidity)

3 forms of chlorine:

- Gas (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)

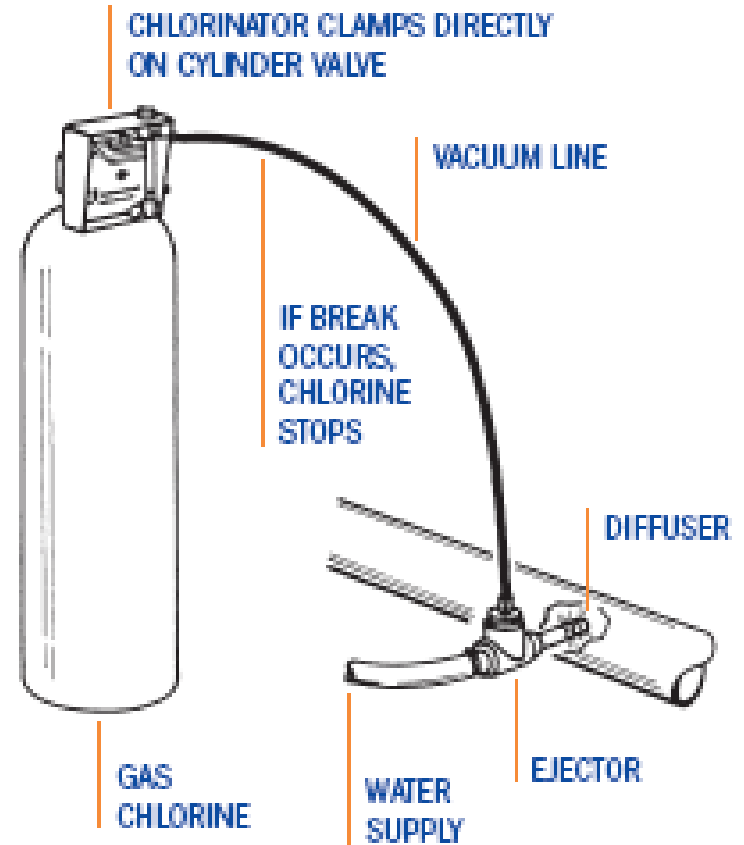
Chlorine tablet: Accu-Tab



**Nursery / woody plants
tolerant**

Chlorine gas: Regal

Regal Gas Chlorinator





www.cals.ncsu.edu/plantpath/extension/clinic/

