

# Disease Management Greenhouse Vegetables

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# High Tunnels & Winter Tunnels

## Environment

is different  
from field



## Diseases

are different  
from field

Higher humidity  
Less leaf wetness  
Higher temperature (HT)  
Lower UV radiation  
Less diversity in rotation

Gray mold (*Botrytis*)  
Downy mildew  
Powdery mildew  
White mold  
Leaf mold (tomato)  
Pith necrosis (tomato)  
Gray leaf spot (tomato)

# **Diseases in High Tunnels: Factors Determining Occurrence**

- Pathogen able to enter.**
- Conditions favorable for infection and disease development. High humidity and high temperature.**

# Diseases in High Tunnels: Occurrence can be unlike field

Photographs taken at one farm on same day.



Septoria leaf spot severe outdoors because spores are water splash dispersed and need wetness to infect.

# **Diseases in High Tunnels:**

## **Sources of Pathogens**

- **Wind-dispersed spores.**
- **Insect vectors.**
- **Alternative hosts (inc. weeds).**
- **Infested seed.**
- **Contaminated soil.**
- **Infested crop debris.**
- **Contaminated tools + supplies.**



**Easy Entry**

# **Diseases in High Tunnels: Environment and Occurrence**

## **Wet Leaf Tissue:**

**Many fungal and bacterial pathogens need for infection.**

## **High Humidity:**

**Adequate for some fungal pathogens to infect.**

# High Tunnel - Diseases of Concern

Foliar fungal pathogens not needing leaf wetness for infection (high humidity)

Bacteria moved mechanically (canker-tomato)

Bacteria + Viruses moved by insects  
(bacterial wilt-cucumbers, TSWV)

Soil-borne root pathogens

Physiological disorders



# Disease Control - High Tunnels

**Compared to field production:**

- **Environment can be modified.**  
Keep humidity low. Minimize leaf wetness. Strive for constant temperature. Avoid wet soils.
- **Crop rotation more challenging.**  
No tolerance for pathogens that can survive in soil.



**Tomato  
White  
Mold**



# Gray Mold





**Powdery Mildew**

**Resistant varieties:  
Geronimo  
Grace**

# Leaf Mold





**Leaf  
Mold**



# Biopesticides

for

High

Tunnel

Tomato

Diseases

## Powdery mildew

Cinnerate

OSO

OxiDate 2

Timorex Act

Aviv

Carb-O-Nator, Kaligreen, MilStop

Cease, Serenade ASO

Double Nickel

LALSTOP G46 WG

Problad Verde

Regalia

Romeo

Serifel

Sporan EC2

Theia

Thyme Guard

Triathlon BA

Trilogy

EcoSwing

ECOWORKS, Rango

FungOUT

GreenFurrow EF 400

Mildew Cure

Prestop

Sonata

Taegro 2

TerraNeem EC

Thymox Control

## Gray mold

Cinnerate

OSO

OxiDate 2

Timorex Act

Aviv

Carb-O-Nator, MilStop

Serenade ASO and Opti

Double Nickel

LALSTOP G46 WG

Problad Verde

Regalia

Romeo

Serifel

Sporan EC2

Theia

Thyme Guard

Triathlon BA

Trilogy

## Leaf mold

Cinnerate

OSO

OxiDate 2

Timorex Act

Brandt Organics Aleo

Companion

Ho wler

LifeGard

Procidic

Stargus

# Biopesticides for Organic and Conventional Disease Management in Vegetables and Strawberries

<https://www.vegetables.cornell.edu/pest-management/disease-factsheets/>

More information:

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Text below updated May 2022

Biopesticides are defined by EPA as pesticides derived from natural materials. There are three types. Biochemical pesticides contain naturally occurring substances that control pests. Substances that control diseases include potassium bicarbonate, hydrogen dioxide, phosphorous acids, plant extracts, and botanical oils. Microbial pesticides contain microorganisms that function as biocontrol agents, affecting the pathogen directly or indirectly through the compounds they produce. Plant-incorporated protectants or PIPs are the least common type of biopesticide. These are pesticidal substances produced by plants that contain genetic material added to the plant often through genetic engineering. The genetic material



# Biopesticides for Organic Production

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Following is a list of some biopesticides that are available for organic production. Each entry follows product name. Most products are registered for use on a variety of crops and diseases of bell and chili pepper are included below. This information is for informational purposes only. Products listed with OMRI (Organic Materials Review Institute) registration: each product may be used on organic crops before purchasing any product. This list does not include the few products that are not permitted in organic production. If you know a biopesticide not listed here, please contact us.

**Actinovate AG.** 0.0371% *Streptomyces* and soil-borne diseases on many crops. Colonizes roots, protecting them from pathogens to plants, which thus are more resistant to diseases. Indicates to use a non-ionic surfactant (formerly Natural Industries, Inc.)

**AgriPhage.** < 1% Bacteriophage and *Pseudomonas syringae* prevention. EPA Reg. No. 67-10000-01

**AgriPhage-CMM.** < 1% Bacteriophage. Labeled for bacterial canker. Not registered. Distributed by Certis USA, LLC

**AVIV.** 0.08% *Bacillus subtilis* spray for gray mold, late blight, powdery mildew, *Phytophthora*, *Rhizoctonia*, and other diseases. EPA Reg. No. 91473-1-86182. Seipasa S.A.

**BioST Nematicide 100.** 95% thionyl chloride. Labeled for several nematodes. Albaugh, LLC.

**Bio-Tam.** 2% *Trichoderma* beneficial fungi have different uses at 45°F) and environmental uses. EPA Reg. No. 100-10000-01

**Brandt Organics Aleo.** 78% potassium bicarbonate. Labeled for bacterial speck, gray mold, and late blight. EPA registration. Brandt CropScience.

**Carb-O-Nator.** 85% potassium bicarbonate. Labeled for powdery mildew. OMRI-listed. EPA Reg. No. 100-10000-01

**Cease.** 1.34% *Bacillus subtilis*. Labeled for bacterial spot, late blight, and gray mold. EPA Fungicide Registration No. 100-10000-01

**Cinnerate.** 60% cinnamon oil. Labeled for and leaf mold. OMRI-listed. EPA Reg. No. 100-10000-01

**Companion.** 0.03% *Bacillus subtilis*. Labeled for including bacterial spot, but also for blight caused by *Sclerotinia* in tomato. EPA Reg. No. 71-10000-01

**DiTera DF Biological Nematicide.** and solubles. Labeled for several nematodes. Valent BioSciences LLC.

**Double Nickel 55 LC and 108.** Broadly labeled for foliar and early blight, gray mold, late blight, *Pythium*, *Phytophthora*, *Rhizoctonia*, and 108, respectively. Certis USA, LLC

**EcoSwing Botanical Fungicide.** early blight) and powdery mildew. EPA Reg. No. 100-10000-01

**ECOWORKS EC.** 70% colchicine. Labeled for anthracnose, etc. and also for nematodes. Technologies LLC.

**FungOUT.** 1.07% citric acid. Labeled for crops. OMRI-listed. Exempt from EPA registration. EPA Reg. No. 100-10000-01

**GreenFurrow BacStop.** 7.5% thyme, 3.0% garlic, 2.0% cinnamon. Labeled for blight and late blight. Exempt from EPA registration. EPA Reg. No. 100-10000-01

**GreenFurrow EF 400.** 5.6% clove. Labeled for diseases of vegetable crops that are caused by mildew, and white mold. Exempt from EPA registration. EPA Reg. No. 100-10000-01

**Howler.** 50% *Pseudomonas* and *Botrytis* (gray mold) and *Colletotrichum*, *Rhizoctonia*, and *Sclerotinia*. Labeled for blight and late blight. Exempt from EPA registration. EPA Reg. No. 100-10000-01

**Kaligreen.** 82% potassium bicarbonate. Labeled for blight and late blight. EPA Fungicide Registration No. 11581-2. Arysta LifeScience North America

**KeyPlex 350 OR.** 0.063% yeast extract. Labeled for proteins (alpha-keto acids) and plants against fungal and bacterial diseases. EPA approval for organic production. EPA Reg. No. 100-10000-01

**LALSTOP G46 WG.** 93% *Gliocladium* soil-borne diseases caused by *Rhizoctonia*, *Sclerotinia*, and *Verticillium* (some species cause mildew. \*These diseases are not registered. Specialties Inc.

**LifeGard WG.** 40% *Bacillus* for bacterial speck, early blight, gray mold, and late blight. EPA Fungicide Registration No. 100-10000-01

**Majestene.** 94.5% heat-killed *Trichoderma* media. Bionematicide for root-knot and ingestion. OMRI-listed. EPA Reg. No. 100-10000-01

**MeloCon WG.** 6% *Paecilomyces* parasitic nematodes, including *Heterodera* nematodes. OMRI-listed. EPA Fungicide Registration No. 100-10000-01

**MilStop.** 85% potassium bicarbonate. Labeled for anthracnose, *Alternaria* (ear rot), and late blight. EPA Reg. No. 100-10000-01

**Minuet.** 9.89% *Bacillus subtilis*. Labeled for *Phytophthora*, *Pythium*, *Rhizoctonia*, and *Sclerotinia*. CropScience.

**Mycostop.** 35% *Streptomyces*. Labeled for seed and root rot in potting mix, applied as a soil drench, or through drip irrigation. EPA Reg. No. 100-10000-01

**Organocide.** 5% sesame oil. Labeled for gray mold, late blight and late blight. EPA Fungicide Registration No. 100-10000-01

**OSO.** 5% polyoxin D zinc salt. Labeled for powdery mildew. OMRI-listed. EPA Reg. No. 100-10000-01

**OxiDate 2.** 27% hydrogen dioxide. Labeled for bacterial spot, early blight, gray mold, and late blight. g Systems, LLC.

**PerCarb.** 85% sodium carbonate. Labeled for speck, early blight, and late blight. EPA Fungicide Registration No. 100-10000-01

**Prestop.** 93% *Gliocladium* soilborne diseases (such as *Phytophthora* and *Verticillium*) and foliar diseases caused by *Fusarium* plus powdery mildew. EPA Reg. No. 64137-10000-01

**Prevont.** Renamed AVIV. EPA Fungicide Registration No. 100-10000-01

**Problad Verde.** 20% Banda. Labeled for anthracnose, bacterial spot, late blight, and powdery mildew. EPA Reg. No. 100-10000-01

**Promax.** 3.5% thyme oil. Labeled for diseases and plant parasitic nematodes. Bio Huma North America

**Rango.** 70% cold pressed thyme oil, and foliar disease applications for nematode control. Labeled for *Rhizoctonia solani* (label trademarked by Terramera, Inc.

**Regalia.** 5% extract of *Regium*. Labeled for certain fungal and bacterial diseases: late blight, *Phytophthora* blight, *Pythium*, and *Rhizoctonia*

**Romeo.** 94.1% cerevisian yeast. Labeled for gray mold, late blight and late blight. Corporation

**RootShield Granules, Aerial, and RootShield Plus WP.** Labeled for transplant roots, soil (greenhouse) roots protecting them again. EPA Reg. No. 6853-10000-01

**RootShield Plus WP.** 1.1% strain G-41. See previous entry.

**Serenade ASO.** 1.34% *Bacillus* colonizes roots and produces auxin to activate the plant's natural defenses. Labeled for anthracnose, bacterial spot, late blight, and powdery mildew. *Rhizoctonia*, Southern blight, and late blight. EPA Reg. No. 100-10000-01

**Serenade Opti.** 26.2% *Bacillus* for bacterial spot, buckeye fruit rot, and late blight. EPA Reg. No. 264-1160. New formula. Serenade Optimum. Bayer CropScience

**Serifel NG.** 11% *Bacillus* for late blight, *Phytophthora* blight, and powdery mildew. EPA Reg. No. 100-10000-01

**Serifel.** 9.9% *Bacillus* for anthracnose, bacterial spot, and late blight, and powdery mildew. EPA Reg. No. 100-10000-01

**Sil-Matrix.** 29% potassium silicate. Labeled for production. OMRI-listed. EPA Reg. No. 100-10000-01

**SoilGard.** 12% *Gliocladium* damping-off and root rot control. Labeled for *capsici* plus *Fusarium* crown rot. EPA Reg. No. 100-10000-01

**Sonata.** 1.38% *Bacillus* for late blight and greenhouse blight. EPA Reg. No. 100-10000-01

**Sporan EC2.** 16% rosenol. Labeled for spot, early blight, gray mold, and late blight. KeyPlex.

**Stargus.** *Bacillus amylophilus*. Labeled for *Phytophthora* blight, and *Verticillium*. OMRI-listed. EPA Reg. No. 100-10000-01

**Taegro 2.** 13% *Bacillus* for speck and spot, early blight, and late blight. Pathogens *Fusarium*, *Phytophthora*, and *Sclerotinia*. Novozymes Biologicals, Inc.

**Tenet WP.** Same as BioSipcamAdvan.

**TerraClean 5.** 27% hydrogen peroxide. Labeled for borne plant diseases such as *Rhizoctonia*; crops not released vast amounts of oxygen. OMRI-listed. EPA Reg. No. 100-10000-01

**TerraNeem EC.** 84.9% clove. Labeled for mildew, and foliar diseases. Applications for nematode control. Labeled for *Rhizoctonia solani* (label trademarked by Terramera, Inc.

**Thymox Control.** 27% thyme oil. Labeled for fungal diseases such as powdery mildew and grey mold, and bacterial diseases; crops not specified. OMRI-listed. Exempt from EPA registration. Kemin Industries, Inc. Manufactured by Laboratoire M2.

**Thyme Guard.** 23% thyme oil extract. Labeled for diseases like *Botrytis* gray mold, late blight, powdery mildew and others caused by fungi, bacteria, viruses, and nematodes; crops not specified. Exempt from EPA registration. Determined to be NOP compliant by Washington State Dept of Ag. Agro Research International.

**Timorex Act.** 12.5% tea tree oil. Labeled for anthracnose, bacterial diseases (speck, spot, canker), early blight, gray mold, late blight, leaf mold, powdery mildew, and applied to soil for damping-off, crown and root rot caused by *Fusarium*, *Pythium*, *Rhizoctonia*, *Sclerotinia*, *Phytophthora*, or *Verticillium*. OMRI-listed. EPA Reg. No. 86182-3-88783. Summit Agro USA, LLC.

**Triathlon BA.** 98.85% *Bacillus amyloliquefaciens* strain D747. Labeled for controlling gray mold and suppressing bacterial speck and spot (label states to tank mix or rotate with copper-based fungicides to improve control), early blight, late blight, powdery mildew, and applied to soil for suppressing damping off, seedling blights, and root or crown diseases caused by *Pythium*, *Rhizoctonia*, *Fusarium*, *Phytophthora*, or *Verticillium* spp. OMRI listed. EPA Reg. No. 70051-107-59807. OHP, Inc.

**Trilogy.** 70% clarified hydrophobic extract of neem oil. Labeled generally for several insects and diseases. Labeled diseases that occur in tomato include anthracnose, early blight, *Botrytis* (gray mold), and powdery mildew (label has separate lists of crops and diseases). OMRI-listed. EPA Reg. No. 70051-2. Certis USA, LLC.

**Zonix biofungicide.** 8.5% rhamnolipid biosurfactant. Kills zoospores, which is one spore type produced by Oomycete pathogens which cause diseases such as late blight. OMRI-listed. EPA Reg. No. 72431-1. PropTera, LLC.

Below are some organic fungicides with active ingredients that are considered to be biocompatible, but the ingredients have not been reviewed by EPA or are not naturally occurring substance and thus are not in the [US EPA biopesticide active ingredient list](#):

**DES-X insecticidal soap.** 47% potassium salts of fatty acids. Labeled for powdery mildew and several insects and mites. OMRI-listed. EPA Reg. No. 67702-22-70051. Certis USA, LLC.

**KOPA insecticidal soap.** 47% potassium salts of fatty acids. Labeled for powdery mildew and several insects and mites. OMRI-listed. EPA Reg. No. 67702-11-59807. OHP, Inc.

**M-Pede insecticidal soap.** 49% potassium salts of fatty acids. Labeled for powdery mildew and several insects and mites. OMRI-listed. EPA Reg. No. 10163-324. Gowan Co.

**Organic JMS Stylet-oil.** 97.1% paraffinic oil. Labeled for several insect pests, viruses vectored by aphids, and powdery mildew. OMRI-listed. EPA Reg. No. 65564-1. JMS Flower Farms, Inc.

**TriTek.** 80% mineral oil. Labeled for several insect pests and powdery mildew. OMRI-listed. EPA Reg. No. 48813-1. Previously named Saf-T-Side. Brandt Consolidated, Inc.

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More information:

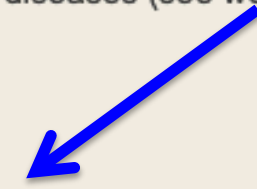
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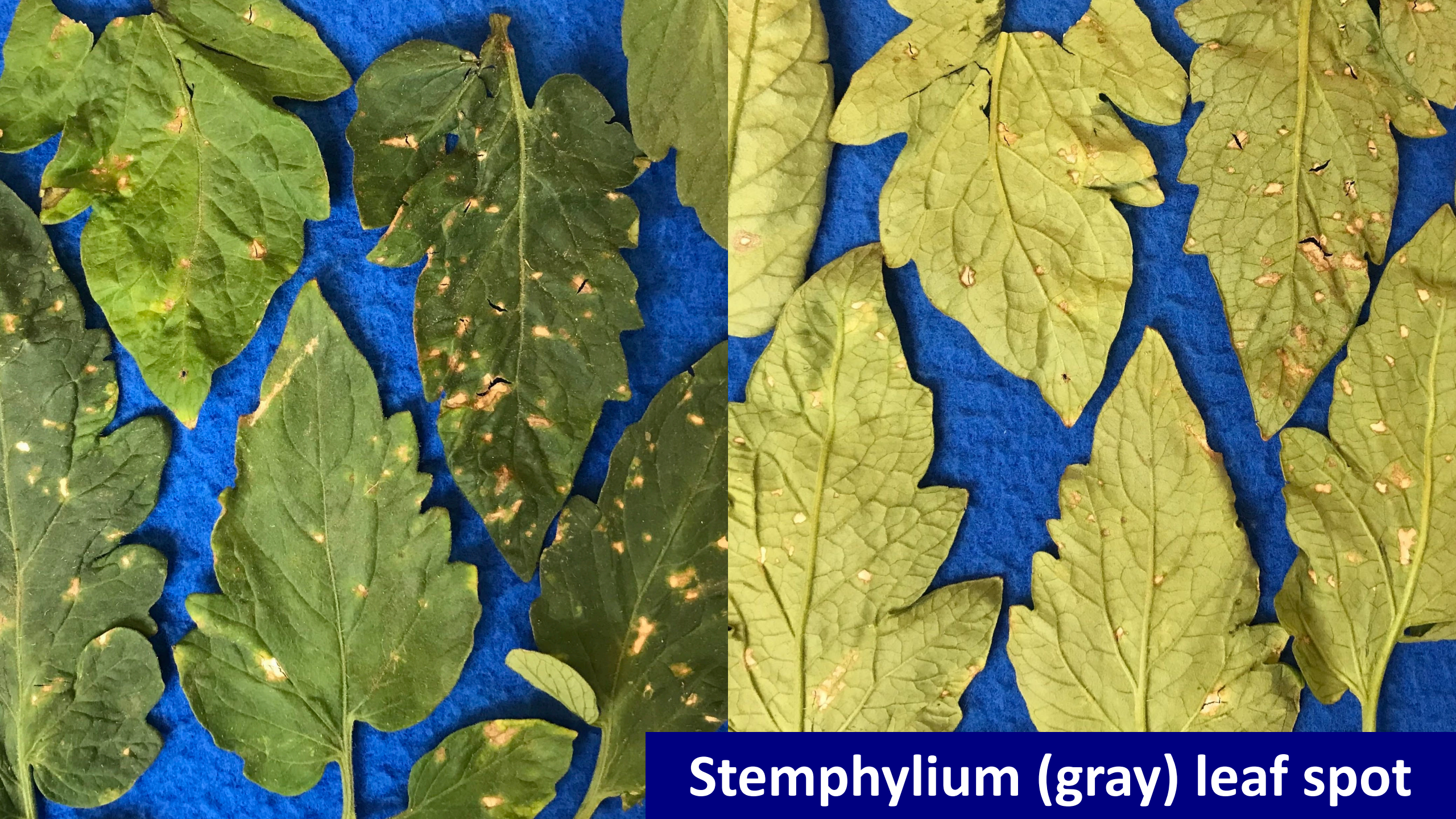


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**Stemphylium (gray) leaf spot**



**Stemphylium (gray) leaf spot**



**Stemphylium  
(gray) leaf  
spot**



**Septoria  
leaf spot**

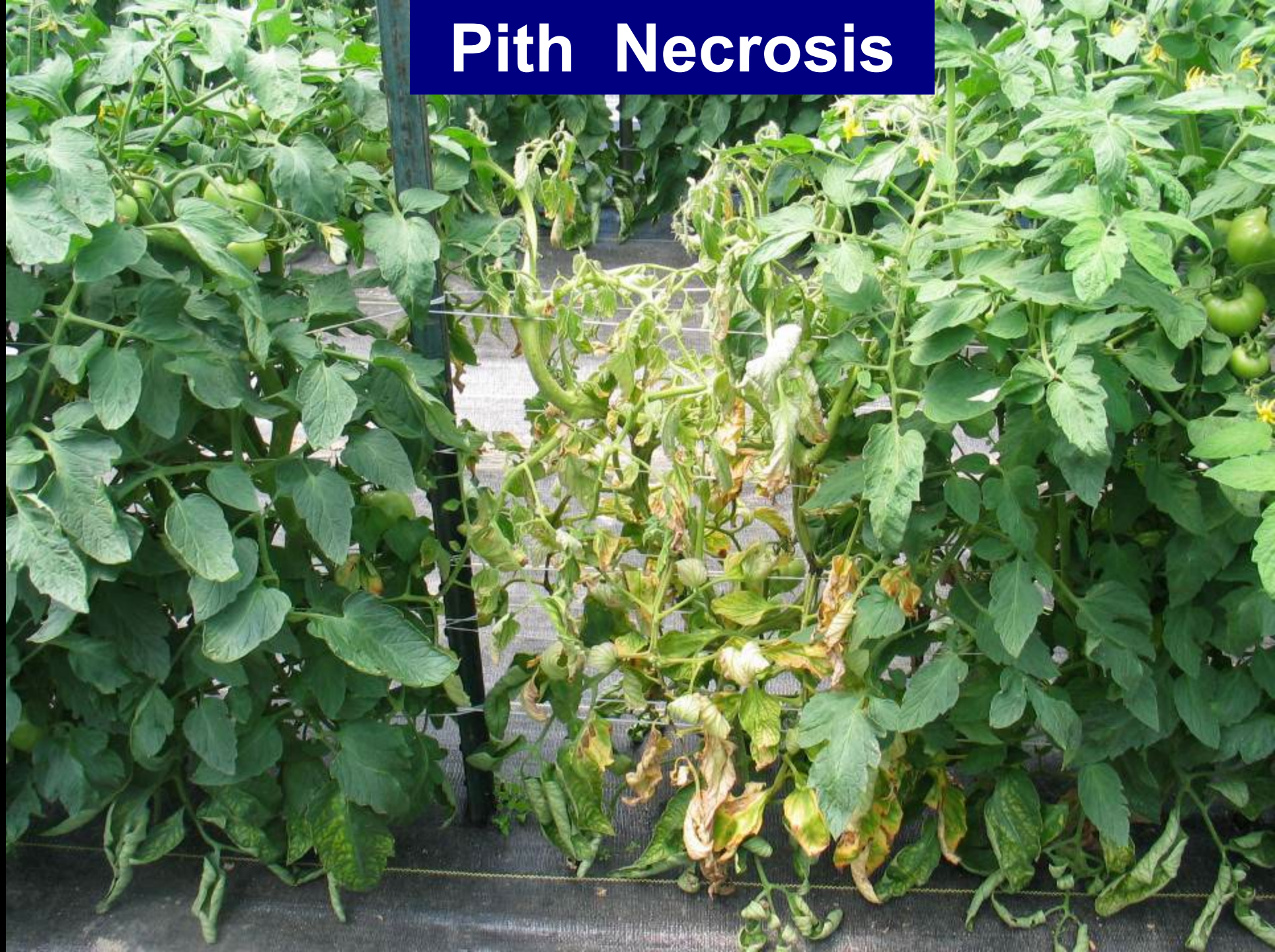


# Stemphylium (gray) leaf spot

Can become severe in  
high tunnels

Rhode Island, cf Andy Radin

# Pith Necrosis









**Pith Necrosis**

# Tomato Pith Necrosis

**1978 cause identified (bacterium)**

**Seed-borne and soil-borne**

**Occurs when first fruit close to mature green**

**Favorable conditions:**

**Excessive N (over vigorous plant growth)**

**High RH during cloudy weather**

**Note – considered difficult to move mechanically**

# Bacterial Wilt – Cucumber

Manage by managing  
cucumber beetles.



cf. Dan Egel, Purdue

# Pythium Root Rot - Tomato



# Disease Control - High Tunnels

## ROOT ROTs

Common, generalist, saprophytic, soil-dwelling fungi  
(*Pythium*, *Rhizoctonia*, etc).

Wide host range.

Most cannot be in seed (exception is Fusarium wilt pathogen).

Manage proactively and aggressively:

Avoid introducing.

Avoid favorable conditions (wet, cool soils; lot of fresh organic matter).

Implement biocontrol. Add compost. Use soil biofungicides.

Biofumigation with mustard cover crop.

Soil solarization.

Obtain diagnosis. Rogue diseased plants.



JUN 5 2006

# Spinach Fusarium Wilt

Can be Seed-borne

*cf. Lindsey du Toit*



JUL 11 2006

# Disease Control – High Tunnel

Locate tunnels for good sunlight and airflow.

Avoid introducing pathogen.

Use pathogen-free seed (tested, treated).

Control weeds inside and near by.

Select resistant varieties. Cucumber – powdery mildew.

Separate crop plantings inside and nearby.

Grow ornamental crops separately.

Proper fertilization (N), temperature, and water.

Minimize humidity. Wide row and plant spacing.

Fans. Open sides. Keep temperature constant.

Rows oriented to air movement. Drip irrigation.

Prune old leaves and dead tissue.

Control condensation.

# Disease Control – High Tunnel

Cover the ground with plastic or organic mulch.

Practice good sanitation.

Wear gloves (essential for smokers).

Disinfect tools and planting materials.

Avoid moving field soil on shoes or tools.

Inspect plants routinely.

Manage insects that can vector pathogens.

Rogue affected plants when appropriate.

Apply appropriate fungicides on regular, preventive schedule. Ensure disease is correctly identified.

Remove crop debris.

Rotate where crops are grown.



# White Mold Biofumigation Solarization

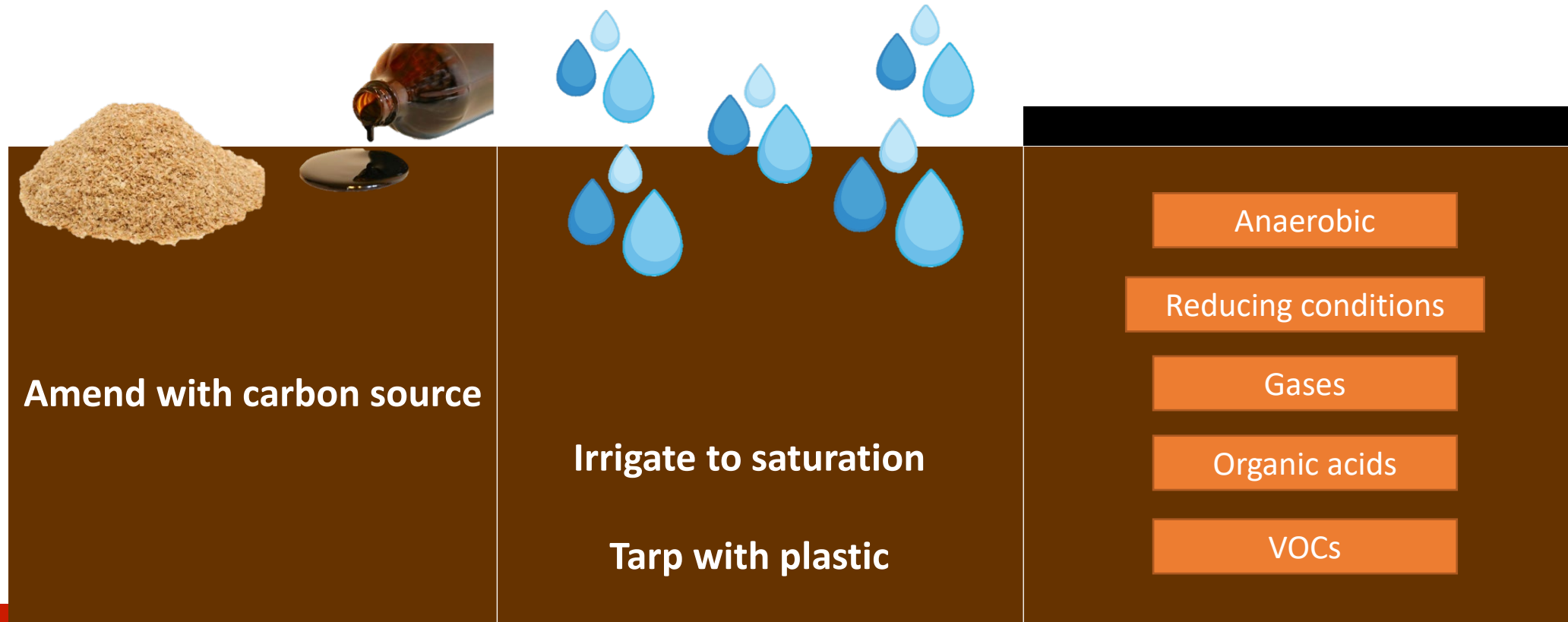


*cf. Paul Vincelli*



# Anaerobic soil disinfestation (ASD)

Utilizes natural processes: microbes break down carbon source under flooded, anaerobic conditions. Oxygen is used up, microbial communities shift and toxic byproducts are produced.





cf. Sally Miller, Ohio State University

# Managing Diseases - Winter Tunnels

Be proactive. Know what diseases can occur + symptoms.

Expect disease occurrence to be different from field.

Be aggressive about management.

Share observations.



[Home](#) > [Pest management](#) > Disease factsheets and articles

## Disease factsheets and articles

If you were a big fan of the pioneering [Vegetable MD Online](#) website, much of that content has been moved here. We are in the process of moving over the rest.

- [\(LIHREC\)](#) indicates information from the Long Island Horticultural Research and Extension Center Vegetable Pathology website.
- List also includes some herbs (parsley, basil) and abiotic disorder
- Some content is available as printer-friendly .pdf versions.

### Get started:

[General tips on diagnosing plant diseases](#)

### Diseases and management practices affecting multiple crops

- [Phytophthora Blight and Its Management in Cucurbit Crops and Other Vegetables](#)
- [Reduced-tillage for Managing Phytophthora Blight and Other Soil-Borne Pathogens](#)
- [Biofumigation for Managing Phytophthora Blight and Other Soil-Borne Pathogens](#)
- [White Mold and Its Management in Cabbage, Beans, and Other Vegetables](#)
- [Diseases of Winter Greens: Downy Mildews, Powdery Mildews, Cladosporium Leaf Spot, and Root Rot](#)

# Diseases Occurring in Winter Greens and their Management

Updated July 2020

This factsheet contains information on the following:

- Downy Mildew of [Spinach](#) | [Lettuce](#) | [Kale and other Brassicas](#)
- [Powdery Mildew of Kale, other Brassicas, and Lettuce](#)
- [Cladosporium Leaf Spot of Spinach](#)
- [Botrytis Crown Rot of Lettuce](#)
- [Root Rot](#)

Additional Information:

- [Downy mildew](#) and [powdery mildew](#) of arugula
- If you grow winter greens [please complete this survey](#).
- [Summary information from survey responses received in 2018](#)
- [What Works for Organic Disease Control in Winter Tunnels](#)
- [Presentation on Organic Disease Control in Winter Tunnels](#) at New England Vegetable and Fruit Conference Dec 2019

## Introduction

Foliar diseases observed recently in winter greens are of special concern. They include downy mildews (spinach, brassicas and lettuce) and powdery mildews (brassicas and lettuce). All are capable of rendering a crop unmarketable. Plants are susceptible at all stages, including cotyledon stage. Their occurrence in field-grown plants in late fall and in winter tunnels is perplexing because most have not been observed recently in these crops grown during traditional production periods, with the exception of brassica downy mildew. Conditions during production of winter greens evidently are very favorable for these pathogens that tolerate cool temperatures. Prolonged periods of leaf wetness or high humidity likely is a factor. Low light levels and short days mean these pathogens have long periods to produce spores. Plastic covering high tunnels protects the pathogens from exposure to damaging UV radiation.

# Managing Diseases - Winter Tunnels

1. Avoid introducing pathogens into tunnel.

Wind-dispersed spores, seed, soil, infested debris.

Hot-water treat seed.

2. Grow resistant varieties. Grow more than one.

Spinach and lettuce downy mildew – race specific resistance – pathogen continuously changing.

3. Create conditions unfavorable for pathogens.

Minimize leaf wetness, humidity, soil moisture.

Drip irrigation, ventilation, heating. Cover plants when leaves dry.

Maintain constant temperature.

4. Look for disease symptoms regularly + thoroughly.

Accurate diagnosis is important.

# Managing Diseases - Winter Tunnels

5. Harvest early when disease found.
6. Promptly remove affected plant tissue.
7. Rotate. Amongst tunnels, years. Manage weeds.
8. Root diseases:
  - Apply biofungicides to soil.
  - Use transplants. Avoid overwatering, but also salt build up.
  - Don't plant soon after incorporating plant tissue.
  - Anaerobic soil disinfestation. Soil solarization. do in summer.
9. Clean row covers.
10. Apply fungicides preventively. Thorough coverage critical for foliar diseases. Esp. with biopesticides.

# Biopesticides for Organic and Conventional Disease Management in Vegetables and Strawberries

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- [Biopesticides labeled for bacterial diseases](#)

<https://www.vegetables.cornell.edu/pest-management/disease-factsheets/>



**More information:**

# Biopesticides for Managing Disease in Leafy Vegetables Organically

[Printer-friendly .pdf version of this page.](#)

Following is a list of some biopesticides labeled for disease control in leafy vegetables. The active ingredient follows product name. Most products are labeled for managing multiple diseases on many crops. The diseases of leafy vegetables specified on these labels and occur in the northeastern U.S. are in the leafy vegetable crop group (EPA group 4-A and 4-B) includes heads of lettuce, arugula, endive, celery, fennel, spinach, Swiss chard, radicchio and other leafy greens. Labels asparagus and watercress are listed with these crops; they are also miscellaneous commodities not assigned to a group under EPA classification. Leafy Brassica greens subgroup (5-B), which includes mustard greens, bok choy, and watercress, is grouped with the leafy vegetable group on some labels. Biopesticides with OMRI (Organic Materials Review Institute) are NOP certified. Some products were reviewed by a different organization. Check state websites to see if a product may not be registered in all states. Also, always check with your grower before purchasing any product. 'No Ag Label' indicates an agricultural use not found for the product. This list does not include the few conventional biopesticides (e.g. phosphorous acid fungicides) that are not permitted in organic production.

If you know a biopesticide not listed, please contact [Meg McGrath](#).  
**Actinovate AG.** 0.0371% *Streptomyces lydicus* strain WYEC 108. Labeled for suppressing several soil-borne and foliar diseases which are listed on the label for crops. Pathogens of leafy vegetables in the list for soil treatment are *Fusarium*, *Phytophthora*, *Pythium*, *Rhizoctonia*, and *Verticillium*. Labeled for treatment for powdery mildew, downy mildew, *Anthracnose*, *Sclerotinia*, and *Erwinia*. Label indicates to use a non-ionic spreader-sticker. EPA Reg. No. 73314-1. Monsanto BioAg (formerly Natural Industries, Inc.)

**AVIV.** 0.08% *Bacillus subtilis* strain IAB/BS03. Labeled for bacterial blight, Cercospora leaf spot, downy mildew, powdery mildew, and Sclerotinia head and leaf drop in leafy vegetables. Replaces Prevont. OMRI-listed. EPA Reg. No. 91473-1-86182. Seipasa S.A.

**BioST Nematicide 100.** 95% heat-killed *Burkholderia* spp. strain A396 cells and spent fermentation media. Labeled for several nematodes including root-knot. OMRI-listed. EPA Reg. No. 84059-14-42750. Albaugh, LLC.

**Bio-Tam.** 2% *Trichoderma asperellum* strain ICC 012 and 2% *Trichoderma gamsii* strain ICC 080. These beneficial fungi have different modes of action and are active over different temperature ranges (starting at 45°F) and environmental conditions. General label with pathogens and crops listed separately. For soil-borne fungal pathogens. Those that can affect leafy vegetables include *Fusarium*, *Phytophthora*, *Pythium*, *Rhizoctonia*, *Sclerotinia*, and *Verticillium*. OMRI-listed. EPA Reg. No. 80289-9-69592. Isagro USA; distributed by Bayer CropScience (formerly AgraQuest).

**Brandt Organics Aleo.** 78% garlic oil. Labeled generally for bacterial and fungal diseases including Pythium damping off. OMRI-listed. Exempt from EPA registration. Brandt Consolidated, Inc.

**Carb-O-Nator.** 85% potassium bicarbonate. Labeled for anthracnose, downy mildew, gray mold, powdery mildew, and Septoria leaf spot. OMRI-listed. EPA Reg. No. 70051-117. Certis USA, LLC.

**Cease.** 1.34% *Bacillus subtilis* strain QST 713. Broadly labeled for use on greenhouse vegetables. Labeled for downy mildew, pink rot, powdery mildew, and Sclerotinia head and leaf drop in leafy vegetables. OMRI-listed. EPA Reg. No. 69592-19-68539. BioWorks, Inc.

**Cinnerate.** 60% cinnamon oil. Labeled for diseases such as powdery mildew and pathogens such as *Botrytis cinerea* which causes gray mold (label has separate lists of crops and diseases). OMRI-listed. Exempt from EPA registration. Seipasa S.A.

**Companion.** 0.03% *Bacillus subtilis* strain GB03. Broadly labeled for foliar and soil-borne diseases, including Alternaria blight, black root rot, bottom rot, Fusarium wilt, gray mold, powdery mildew, Sclerotinia lettuce drop, and root rot caused by *Pythium* and *Rhizoctonia* in leafy vegetables. EPA Reg. No. 71065-3. Growth Products, Ltd.

**Contans WG.** 5.3% *Paraconiothyrium minitans* strain CON/M/91-08. Soil-applied product for *Sclerotinia sclerotiorum* (white mold pathogen). OMRI-listed. EPA Reg. No. 72444-1. SipcamAdvan.

**DiTera DF Biological Nematicide.** 90% *Myrothecium verrucaria* strain AARC-0255 fermentation solids and solubles. Labeled for several nematodes including root-knot. OMRI-listed. EPA Reg. No. 73049-67. Valent BioSciences LLC.

**Double Nickel 55 LC and WDG.** *Bacillus amyloliquefaciens* strain D747, 98.8% and 25%, respectively. Broadly labeled for foliar and soil-borne diseases, including bacterial blights, bottom rot, Cercospora leaf spot, downy mildew, Sclerotinia head and leaf drop, pink rot, powdery mildew, and damping off, root rot and crown rot caused by *Pythium*, *Fusarium*, *Phytophthora*, *Verticillium*, and *Rhizoctonia* in leafy vegetables. OMRI-listed. EPA Reg No. 70051-107 and 108, respectively. Certis USA, LLC.

**EcoSwing Botanical Fungicide.** 82% extract of *Swinglea glutinosa*. Labeled for powdery mildew. OMRI-listed. EPA Reg. No. 10163-357. Gowan Co.

**ECOWORKS EC.** 70% cold pressed neem oil. Labeled generally for powdery mildew, downy mildew, leaf spot, botrytis, anthracnose, etc. and also several insects and mites. OMRI-listed. EPA Reg. No. 89152-4. ECOSTADT Technologies LLC.

**FungOUT.** 1.07% citric acid. Labeled for powdery mildew in field and greenhouse crops. OMRI-listed. Exempt from EPA registration. AEF Global Inc.

**GreenFurrow BacStop.** 2.0% thyme, 2.0% clove & clove oil, 1.5% cinnamon, 1.0% peppermint & peppermint oil, and 1.0% garlic oil. Broadly labeled primarily for bacterial diseases; diseases not specified for some crops including leafy vegetables. Exempt from EPA registration. Mar Vista Resources.

**GreenFurrow EF400.** 8.2% clove, 8.1% rosemary, and 6.7% peppermint oils. Labeled for downy mildew, powdery mildew, and Sclerotinia white mold in leafy vegetables. Exempt from EPA registration. Mar Vista Resources.

**Howler.** 50% *Pseudomonas chlororaphis* strain AFS009. Labeled for foliar spray for diseases caused by *Botrytis* (gray mold) and soil treatment for *Fusarium*, *Phytophthora*, *Pythium*, *Rhizoctonia*, and *Sclerotinia*.



# Foliar Diseases – Winter Greens

## Downy Mildew Pathogens:

|            |   |
|------------|---|
| Spinach    | <i>Peronospora farinosa</i> f. sp. <i>spinaciae</i> |
| brassicas* | <i>Peronospora parasitica</i>                       |
| Lettuce    | <i>Bremia lactucae</i>                              |

## Powdery Mildew Pathogens:

|            |                               |
|------------|-------------------------------|
| brassicas* | <i>Erysiphe cruciferarum</i>  |
| Lettuce    | <i>Erysiphe cichoracearum</i> |

\* Brassicas include kale, arugula, Bok choy, and mustard greens.

Host specificity?



# Spinach

## Downy Mildew (aka Blue Mold)



**Race specific resistance. Excellent.**

**Races detected in northeast recently:**

**12, 13, 14 (most cases), 15, 16, 17, novel**

Images cf. Teresa Rusinek, Cornell



19  
Races  
so far

Images cf. grower

# Spinach Downy Mildew: Race specific resistance. Excellent.



## Corvair

Organic (F1) Spinach Seed

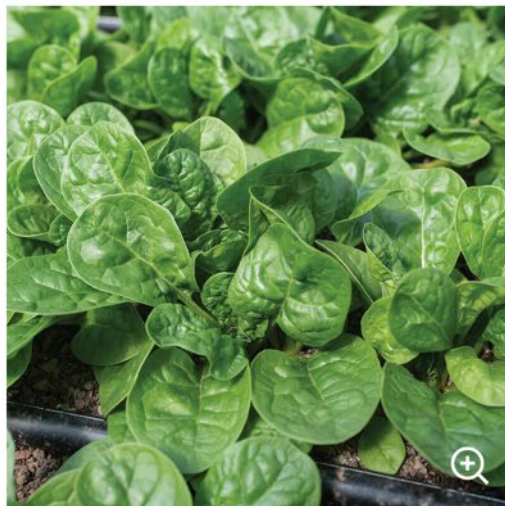
Product ID: 2571G

Organic all-season spinach.

Very dark green, uniform, round leaves. Slow-bolting plants for baby and full size. High resistance to downy mildew races 1-11, 13, 15, 16, 18. USDA Certified Organic. Avg. 44,700 seeds/lb. Packet: 1,000 seeds.

Races 1 - 11, 13, 15, 16, 18

Races 1 - 19; 10 IR



## Sunangel

(F1) Spinach Seed

Product ID: 4542

Heavily savoyed DMR spinach for spring, fall, and winter.

A good balance of speed, dark color, savoy, and bolt tolerance for ample harvests through most of the year. More uniform and upright than Emperor, with a less cupped leaf. High resistance to downy mildew races 1-9, 11-19 and intermediate resistance to race 10; intermediate resistance to white rust. Avg. 25,500 seeds/lb. Packet: 1,000 seeds.

# Spinach Downy Mildew

Pathogen races detected in Northeast recently, affected variety and its resistance

|                    |                                  |
|--------------------|----------------------------------|
| 12, 14 (4X), novel | Corvair (1 – 11, 13)             |
| 12                 | Acadia (1 - 13, 15, 16)          |
| 14                 | Kookaburra (1 - 13, 15)          |
| 15                 | Space (1, 2, 3, 5, 6, 8, 11, 12) |
| novel              | Escalade (1 - 14, 16)            |
| novel              | Pigeon (1 - 13, 15)              |

Races suspected based on varieties affected and not:

12, 13, 14 (most cases), 15, 16, 17, novel.



Images cf. grower

19  
Races  
so far

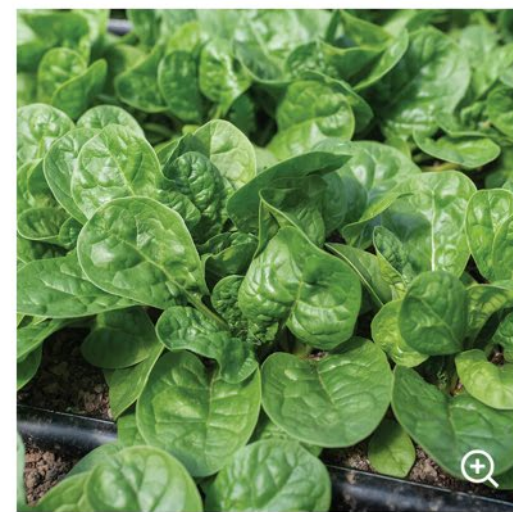
# Spinach Downy Mildew: Race specific resistance. Excellent.



**Corvair** Product ID: 2571G  
Organic (F1) Spinach Seed  
  
Organic all-season spinach  
  
Very dark green, uniform, round leaves. Slow bolting plants for baby and full size. High resistance to downy mildew races 1-11, 13, 15, 16, 18. USDA Certified Organic. Avg. 44,700 seeds/lb. Packet: 1,000 seeds.

Races 1 - 11, 13, 15, 16, 18

Races 1 - 19; 10 IR



**Sunangel** Product ID: 4542  
(F1) Spinach Seed  
  
Heavily savoyed DMR spinach for spring, fall, and winter.  
  
A good balance of speed, dark color, savoy, and bolt tolerance for ample harvests through most of the year. More uniform and upright than Emperor, with a less cupped leaf. High resistance to downy mildew races 1-9, 11-19 and intermediate resistance to race 10; intermediate resistance to white rust. Avg. 25,500 seeds/lb. Packet: 1,000 seeds.



19  
Races  
so far

# Spinach Downy Mildew:

**Race specific resistance. Excellent.**



**Auroch**  
(F1) Spinach Seed

Product ID: 4056

Fast growing, upright variety for the winter tunnel.

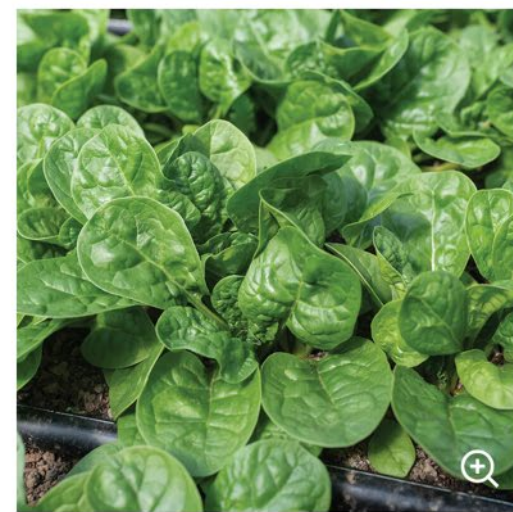
Very tall plants with very long stems. Leaves are dark green, very heavy, smooth, and flat with elongated oval shape. Suitable for picking at all growth stages. Performs best in fall, winter, and early spring. High resistance to downy mildew races 1-12, 14-16, 19. Avg. 38,900 seeds/lb. Packet: 1,000 seeds.

**Races 1 - 12, 14 - 16, 19**

**Races 1 - 19; 10 IR**



Grow  
more  
than  
one  
variety



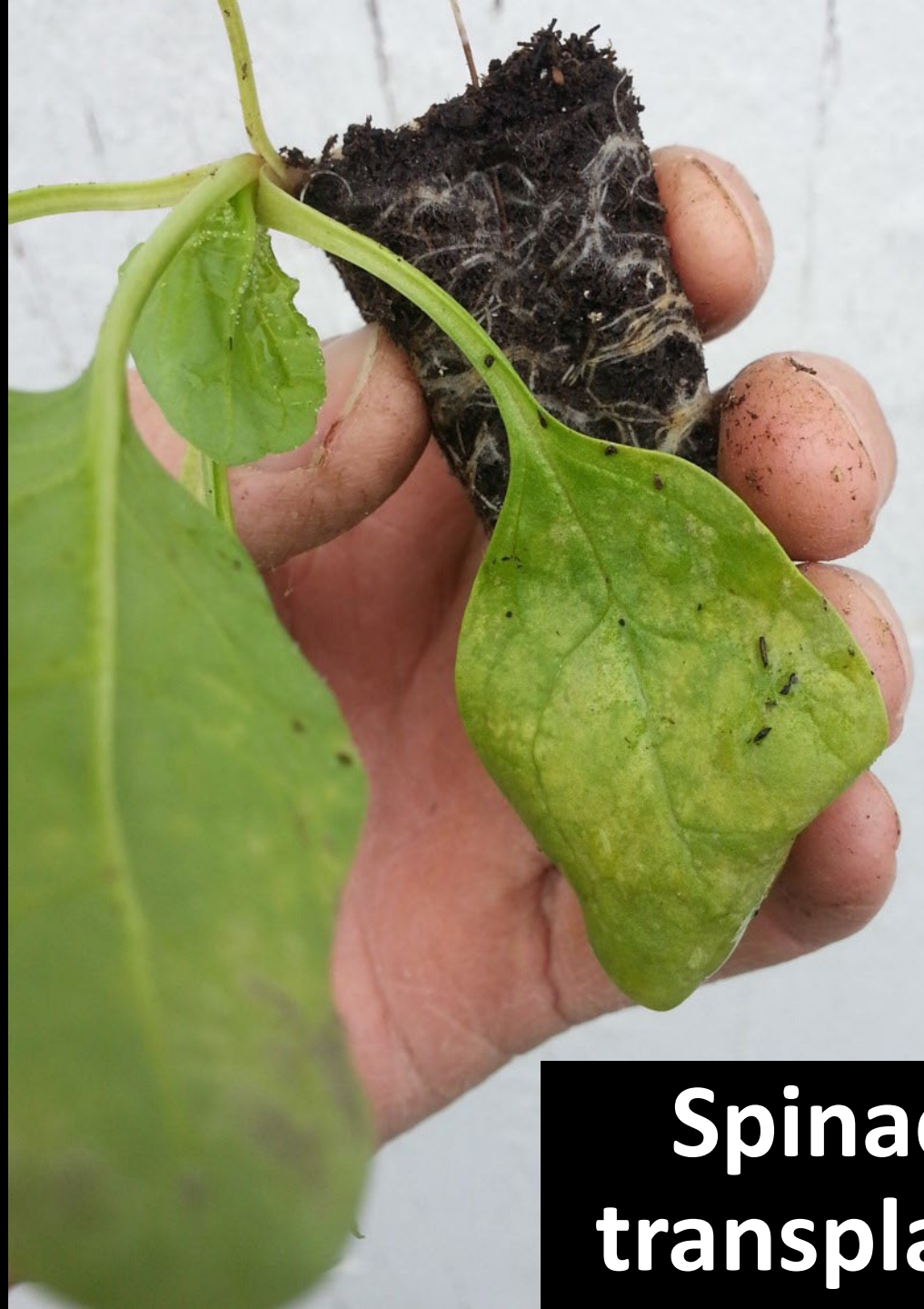
**Sunangel**  
(F1) Spinach Seed

Product ID: 4542

Heavily savoyed DMR spinach for spring, fall, and winter.

A good balance of speed, dark color, savoy, and bolt tolerance for ample harvests through most of the year. More uniform and upright than Emperor, with a less cupped leaf. High resistance to downy mildew races 1-9, 11-19 and intermediate resistance to race 10; intermediate resistance to white rust. Avg. 25,500 seeds/lb. Packet: 1,000 seeds.

**Apr 2017**



**Spinach  
transplants**

Images cf. grower

# Spinach Downy Mildew

## Potential sources of pathogen

Seed? Oospores found but ability to infect seedlings not determined.

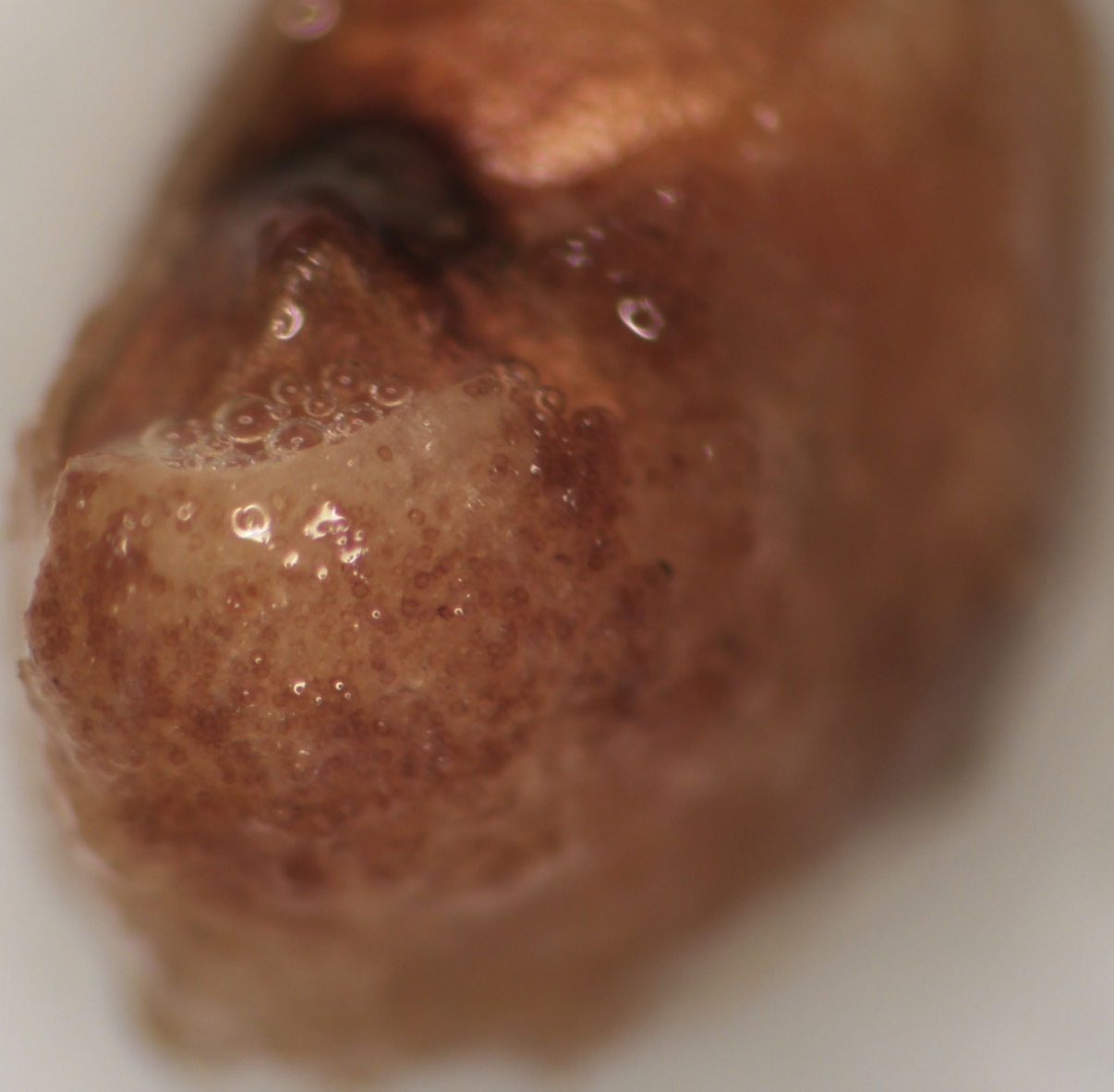
Wind dispersed spores (sporangia) from other crops.

Also discarded produce??

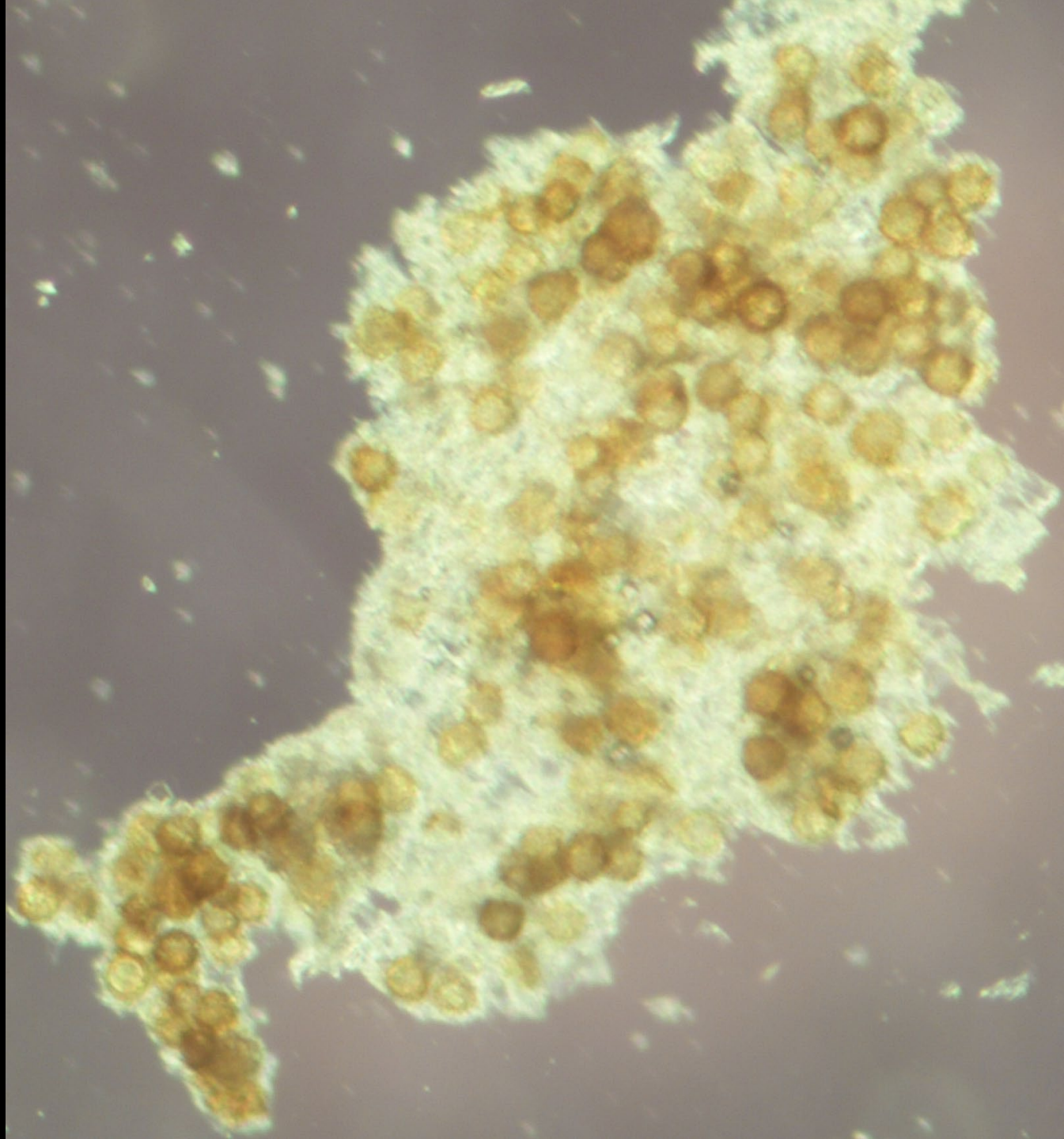
## Occurs routinely in AZ and CA (field)

Managed with resistant varieties (race specific) and conventional fungicides.





**Oospores embedded in  
Corvair seed**

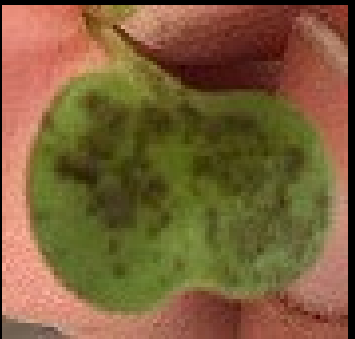


**Arugula**  
**Downy**  
**Mildew**





# Bacterial Blight Arugula



# Lettuce - Downy Mildew



Yellow spots upper surface

Oct 2009



Spores underneath





1 Nov 2017

Spores upper surface



1 Nov 2017

Spores  
all over  
upper  
surface



27 Nov 2017



# Lettuce Downy Mildew

Multiple races. Resistance is race specific.

Other hosts include: wild lettuce, artichoke, cornflower, and strawflower. Pathotypes infect specific plants.

Damp, cool conditions and moisture on leaves required for infection. 3+ hours.

Spores form during still, humid nights (dark). 68 F = optimum; Occurs 41 – 75 F. Bright sunlight and low humidity inactivate spores.

Latent period (4 - 34 days). Long when continuously cool. Short under fluctuating low temperatures.

Sources: seed, sexual spores (oospores, rarely seen), and wind-blown asexual spores.

Common in CA lettuce growing areas.

High  
Tunnel

Powdery  
Mildew  
Lettuce



# Lettuce Powdery Mildew

Other hosts include: chicory, endive, globe artichoke, bull-thistle, sunflower, and cucurbits (uncommon).

Optimum for spore germination:

64 F.

95 – 98% relative humidity. 100% inhibits.

Common in field in Yuma, AZ (major lettuce growing area).

Rare in eastern USA, except greenhouses + winter tunnels.

Sources: wind-blown asexual spores and over-wintering sexual spores (ascospores in chasmothecia).

16 Nov 2016  
High tunnel

## Powdery Mildew-Kale



White  
Russian  
and  
Red Ursa  
affected;  
not  
Winterbor.

**ORGANIC:**  
Stylet-oil +  
MilStop  
seen to be  
effective.

Image cf. Teresa Rusinek, Cornell



Images cf. growers

Cladosporium  
Leaf Spot

Spinach



Winter  
Bloomsdale  
is a less  
susceptible  
variety



# Stemphylium Leaf Spot Spinach - field



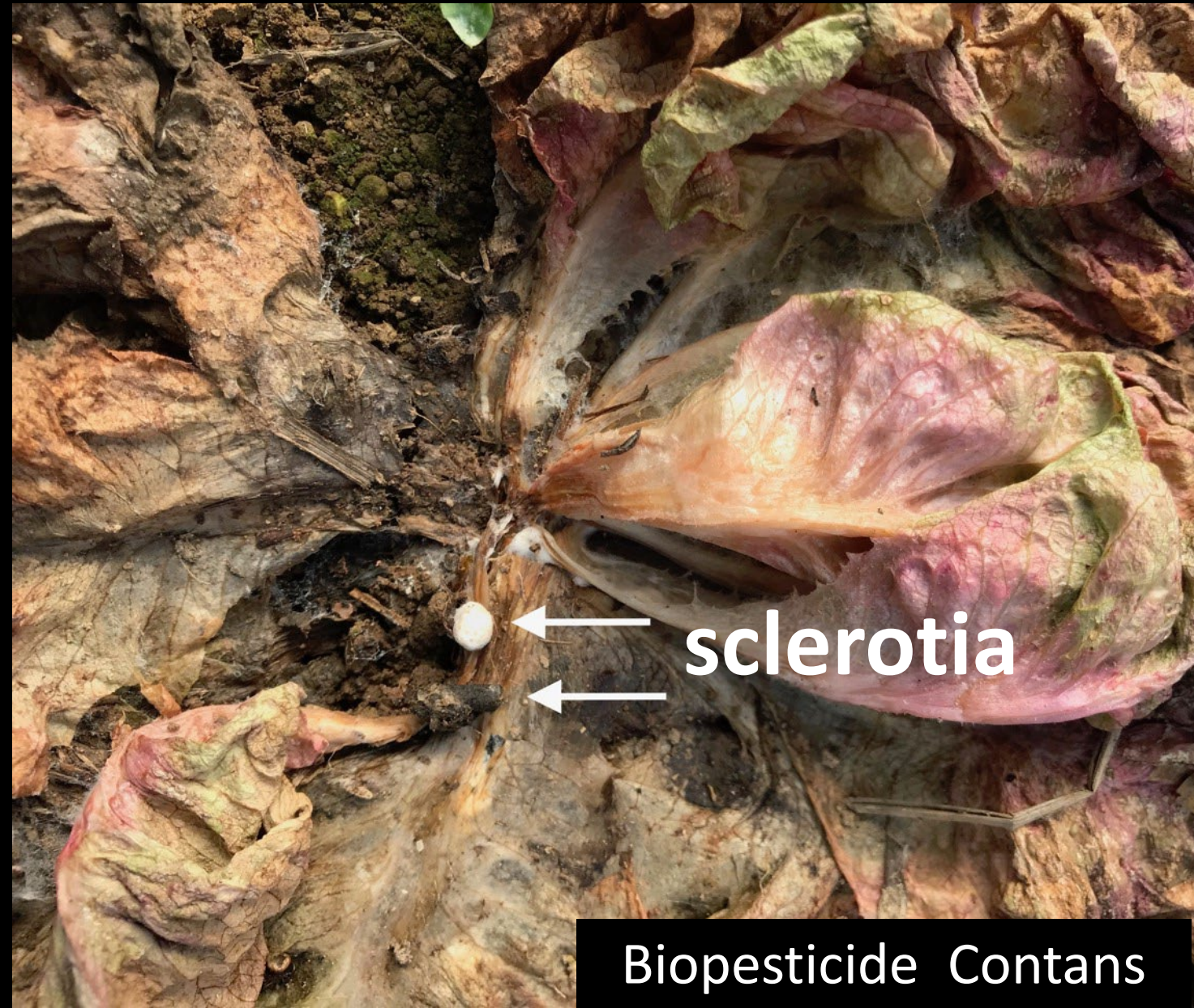
## Cladosporium and Stemphylium leaf spots

Sources: infested seed, wind-dispersed spores, crop debris.

Favorable conditions: 59 – 68 F and RH > 80%.

Range 41 – 86 F.

# White Mold - Lettuce



Biopesticide Contans



# Botrytis Crown Rot - Lettuce

Images cf. grower





# Botrytis Gray Mold

Large host range.

Wind-dispersed  
spores.

Manage humidity.

Images cf. Teresa  
Rusinek, Cornell





**Thank you!**

