

Managing Disease in High Tunnel Winter Greens

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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.

Cornell Vegetables

Resources for commercial growers

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[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](#)

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

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

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

Biopesticides registered in New York for specific crops with labeled diseases occurring in the Northeast

Lists do not include the few conventional biopesticides (e.g. phosphorous acid fungicides) that are not permitted in organic production.

- [Beet](#)
- [Brassica crops](#)
- [Bulb crops](#)
- [Carrot](#)
- [Cucurbit crops](#)
- [Eggplant](#)
- [Leafy vegetables](#)
- [Pepper](#)
- [Potato](#)
- [Strawberry](#)
- [Tomato](#)
- [Biopesticides labeled for bacterial diseases](#)

More information:

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



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 head 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, is grouped with the leafy vegetable group on some labels. Products 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 only product found for the product. This list does not include the few conventional pesticides (e.g. phosphorous acid fungicides) that are not permitted in organic production.

If you know a biopesticide not listed, please contact [Meg McGrath](#) at meg.mcgrath@cornell.edu.

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 include *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 Nemacide 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.

Cinnarate. 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*, *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



Images cf. grower

19
Races
so far

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

Organic (F1) Spinach Seed

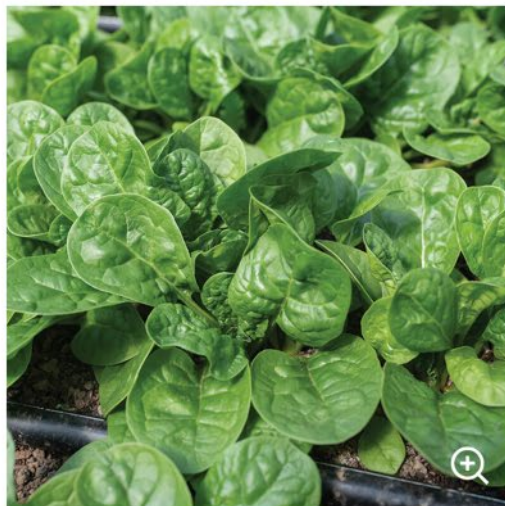
Product ID: 2571G

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.



19
Races
so far



Grow
more
than
one
variety

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



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)

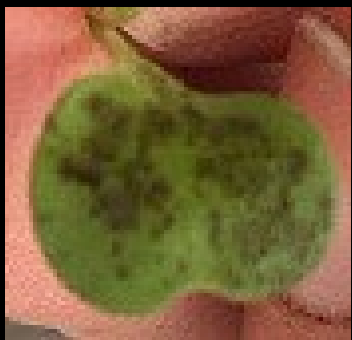
Managed with resistant varieties (race specific) and conventional fungicides.

Arugula
Downy
Mildew





Bacterial Blight
Arugula

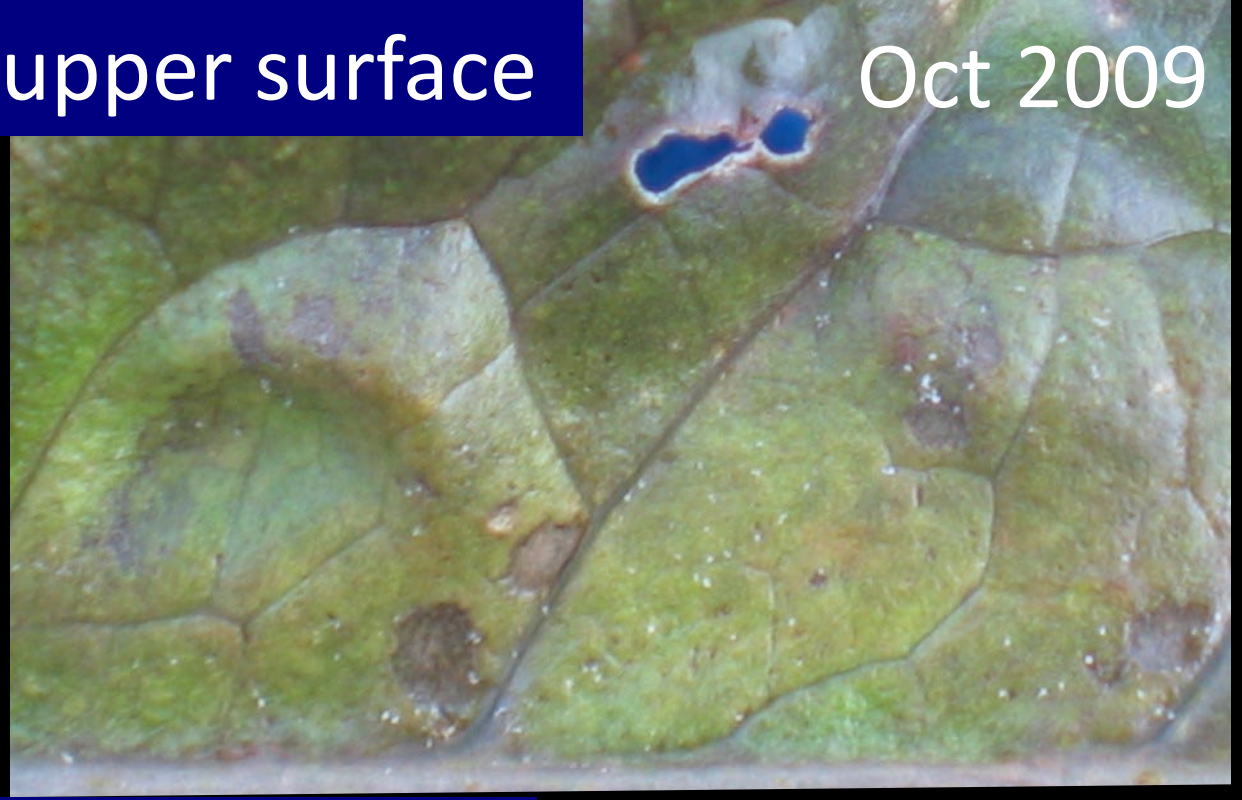


Lettuce - Downy Mildew



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



Cladosporium
Leaf Spot

Spinach



Winter
Bloomsdale
is a less
susceptible
variety



Images cf. growers

Stemphylium Leaf Spot

Spinach - field

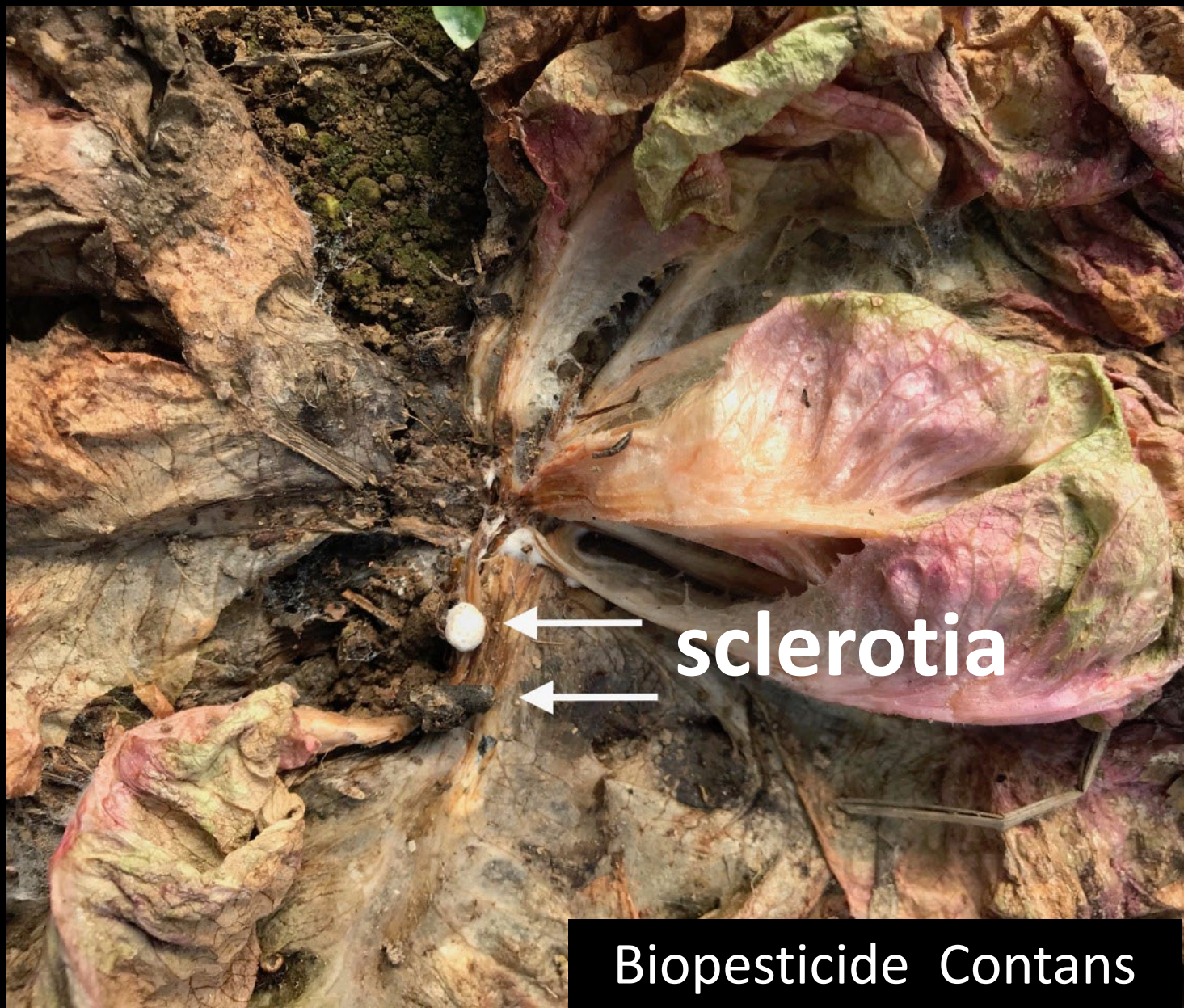


Cladosporium and Stemphylium leaf spots

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

Favorable conditions: 59 – 68 F and RH > 80%.
Range 41 – 86 F.

White Mold - Lettuce



sclerotia

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



QUESTIONS

about

**Managing Disease in
High Tunnel Winter Greens**

???

