Disease Management
Greenhouse Vegetables

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High Tunnels & Winter Tunnels

Environment
is different from field

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

Diseases
are different from field

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.
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.
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
Compared to field production:

- **Environment can be modified.**

- **Crop rotation more challenging.**
  No tolerance for pathogens that can survive in soil.
Tomato White Mold
Gray Mold
Powdery Mildew

Resistant varieties:
- Geronimo
- Grace
<table>
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Biopesticides for Organic and Conventional Disease Management in Vegetables and Strawberries

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Biopesticides registered in New York for specific crops
Northeast

Lists do not include the few conventional biopesticides (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

- Tables of biopesticides to facilitate comparing products for labeled diseases (see webpages above for more information about the products):
- Table of biopesticides organized by type of active ingredient
- Database of results from biopesticide evaluations published in PDMR (.xls)
- References for results from biopesticide evaluations in database
- Efficacy of microbial biopesticides published in PDMR (summary of results for products tested singly from database linked above)
- Efficacy of biochemical biopesticides and copper published in PDMR (summary of results for products tested singly from database linked above)
- Evaluations of Biopesticides and other Organic Fungicides conducted at LIHREC
- Biocontrol Bytes biopesticides posts (blog from Amara Dunn, Biocontrol Specialist, NYSIPM)

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 and Conventional Disease Management in Vegetables and Strawberries

More Information:

- Tables of biopesticides to facilitate comparing products for labeled diseases (see webpages above for more information about the products):
  - Cucurbit crops: .pdf .xlsx | Tomatoes: .pdf .xlsx
- Table of biopesticides organized by type of active ingredient
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Stemphylium (gray) leaf spot
Stemphylium (gray) leaf spot
Septoria 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
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
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.
Spinach Fusarium Wilt

Can be Seed-borne

cf. Lindsey du Toit
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.
  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.

Amend with carbon source

Irrigate to saturation

Tarp with plastic

Anaerobic
Reducing conditions
Gases
Organic acids
VOCs

cf. Sally Miller, Ohio State University
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.
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.
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.
10. Apply fungicides preventively. Thorough coverage critical for foliar diseases. Esp. with biopesticides.
Biopesticides for Managing Diseases on Leafy Vegetables Organically

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Following is a list of some biopesticides labeled for disease control. The active ingredient follows product name. Most products are managing multiple diseases on many crops. The diseases of leafy vegetables specified on these labels occur in the northeastern US. It is advisable to rotate crops of leafy vegetables. Brassica greens subgroup (5-B), which includes mustard greens, collard greens, kale, and turnip greens, is grouped with the cabbage and greens subgroup. These crops are grown in the same fields and have the same pest and disease problems.

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

Lists do not include the following biopesticides (e.g., phosphon acid fungicides) which 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/
Foliar Diseases – Winter Greens

Downy Mildew Pathogens:
- Spinach: *Peronospora farinosa f. sp. spinaciae*
- brassicas*: *Peronospora parasitica*
- Lettuce: *Bremia lactucae*

Powdery Mildew Pathogens:
- brassicas*: *Erysiphe cruciferarum*
- Lettuce: *Erysiphe cichoracearum*

* 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
Spinach Downy Mildew: 
Race specific resistance. Excellent.

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

Corvair
Organic (F1) Spinach Seed

- Organic all-season spinach.

Races 1 - 19; 10 IR

Sunangel
(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.
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.
Spinach Downy Mildew:
Race specific resistance. Excellent.

19 Races so far

Images cf. grower

Corvair
Organic (F1) Spinach Seed

Organic all-season spinach.


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

Races 1 – 19; 10 IR

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Spinach Downy Mildew: 
Race specific resistance. Excellent.

Auroch 
(F1) Spinach Seed

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.

Sunangel 
(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.

Races 1 - 12, 14 - 16, 19
Races 1 – 19; 10 IR
Spinach transplants

Apr 2017

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

Images cf. Shaheen Bibi, PSU
Lettuce - Downy Mildew
Yellow spots upper surface

Spores underneath

Oct 2009
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 (ascosporos 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.
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.
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!