Diseases in Vegetable Seed Crops: Identification, Biology & Management

Lindsey du Toit
Washington State University
Mount Vernon Research & Extension Unit
diagnosis of plant problems

biotic

pathogenic:
1. fungal
2. bacterial
3. viral
4. nematode

insect/mite:
1. feeding habit
2. life “cycle”

“macro” organisms

abiotic

physical
chemical
mechanical
Effects of diseases of vegetable seed crops

- yield loss
- infection of harvested seed
- reduction in seed germination & vigor
- seed transmission of pathogen(s) to new crops
Classes of seedborne microorganisms

1. Infected seed = primary inoculum source. If seed infection is controlled, the disease is controlled

3. Important crop pathogen, but infected seed = minor source of inoculum

5. Seedborne microorganisms never demonstrated to cause disease

7. Pathogens that infect seed in fields or in storage, and reduce seed quality
pathogen life cycle

- inoculation
- penetration
- infection & colonization
- dissemination
- growth & reproduction
- survival
seed transmission

production

crop

seed or

crop

production

infection

survival

seed storage

& conditioning

disease development

seedborne disease cycle
disease

pathogen

environment

host
Disease management in seed crops

• cultural practices

• chemical applications, seed treatments

• disease resistance
Disease management in seed crops: Cultural practices

- Crop rotation
- Elimination of alternative hosts
- Destruction of inoculum in the field
- Control of insect vectors
- Irrigation practices
- Planting practices
- Ventilation of seed crops
- Fertilizer programs
- Transplanting
- Harvesting
- Geographical location
Disease management in seed crops: Cultural practices

**Crop rotation**
- non-host, resistant, or ‘antagonistic’ crops
- duration dependent on pathogen host range, foliar vs. soilborne pathogens, longevity of inoculum survival, resistance of cultivar or parent lines cultural practices, etc.
- be aware of asymptomatic hosts

**Elimination of alternative hosts**
- weeds
- volunteers
- adjacent crops
Evaluation of mustard vs. winter wheat cover crops in spinach seed production
Biomass (g/0.15 m²) of weeds and spinach seed crop on 6/13/03 following incorporation of mustard cover crops

The diagram shows the biomass comparison of weeds and spinach seed crop across different treatments:

- Metam sodium
- B. juncea
- B. juncea + B. hirta
- Mustard seedmeal
- Winter wheat

The biomass values are indicated by different bars, with the highest values marked with 'a' and lower values marked with 'b'. The legend indicates that yellow bars represent weeds and green bars represent the spinach crop.
% weed control of shepherd’s purse & lambsquarters on 6/13/03, using mustard cover crops prior to spinach seed production

- Metam sodium
- B. juncea
- B. juncea + B. hirta
- Mustard seedmeal
- Winter wheat

Shepherds purse Lambs-quarters
Disease management in seed crops: Cultural practices

Destruction of inoculum in the field

- remove, or reduce, amount of infected debris or remaining seed after harvest
- reduce inoculum of soilborne pathogens
- burn stubble/debris
- vacuum fields
- fumigation (synthetic, biofumigation)
- soil solarization
- incorporate infested debris into the soil
Overwintering of spinach leaf spot fungi in western Washington

*Cladosporium variabile* on volunteer spinach

*Stemphylium botryosum* on spinach seed stalk debris
Survival of *Stemphylium botryosum* on spinach debris: Surface vs. buried debris
Disease management in seed crops: Cultural practices

Irrigation practices

• reduce duration of leaf wetness, splash dispersal, relative humidity

• e.g., drip vs. furrow vs. overhead irrigation

• economics, practicality?

• timing of irrigation
Incidence of plants on which *Xanthomonas campestris* pv. *carotae* was detected in drip vs. overhead-irrigated sections of 4 carrot seed crops in central Oregon, 2002/03
Disease management in seed crops: Cultural practices

Planting practices
• planting date selected to escape inoculum
  - insect vectored pathogens
  - pathogens that don’t overwinter in the region
• planting date selected for unfavorable conditions for pathogens &/or favorable for crop
• row spacing, plant spacing
• row orientation

Ventilation practices
• thinning
• canopy management for maximum air circulation
Brassica seed crop ventilation through row orientation, row spacing, & staking/tying
Disease management in seed crops: Cultural practices

Transplanting & hygiene

- avoid mechanical injury during transplanting
- avoid dipping transplants in water
- mechanical transmission of pathogens by workers:
  - *Septoria apiicola* in celery
  - *Xanthomonas campestris pv. campestris* in cabbage
  - *tobacco mosaic virus* (TMV) transmission on hands of smokers
Disease management in seed crops:

**Cultural practices**

**Geographical location**

- continental level: grow seed crops in environments unfavorable for disease
  - bean seed in ID & CA to avoid bacterial blights & anthracnose
  - pea seed ID, WA, CA to avoid *Pseudomonas pisi* & Ascochyta blight
  - crucifer seed in WA to avoid blackleg & black rot
  - sweet corn seed in ID & WA to avoid Fusarium ear rots
- local level: avoid frost pockets, areas prone to fogs or dews
Disease management in seed crops: Chemical applications & seed treatment

• organic & biological materials
  - e.g., sulfurs, coppers, Serenade, AQ10, Contans, ...
  - 2002 Plant Health Progress article by McSpadden Gardener and Fravel
  - consistency, niche environments?
  - potential phytotoxicity

• natural plant products
  - oils, plant extracts, compost teas, ...
  - reliability, consistency?

• bicarbonate fungicides
  - powdery mildews
2000/01 Brussels sprouts seed crop fungicide trial

White mold (*Sclerotinia sclerotiorum*)


Incidence on 07/01/01 (% infected plants)

Control  Pristine (BAS516)  Elevate  Serenade  Rovral/Bravo  Switch

Legend:
- **a**
- **b**
- **c**
2002/03 Cabbage fungicide trial
White mold (Sclerotinia sclerotiorum)
In vitro efficacy of fungicides against *Botrytis aclada*, causal agent of neck rot/scape blight of onions

6 days after plating on fungicide-amended agar
In vitro efficacy of fungicides against *Botrytis aclada* (7 days after plating on fungicide-amended agar)
Methods of seed treatment

- physical
- chemical
- biological
Physical seed treatments

- hot water
  - kill pathogens, not damage seed
    - *Phoma lingam* and *Xanthomonas campestris pv. campestris* on cabbage seed exposed to hot water at 50°C for 30 minutes
- hot dry air
- aerated steam
- microwaves
- others, e.g., cathode rays, ultrasound
Chemical seed treatments

- chlorine = surface disinfestation
  e.g., Xanthomonas campestris pv. carotae on carrot seed
- fungicides – various products, but few qualify for organic production
- insecticide seed treatments for vector control (e.g., Gaucho), but few organic

Biological seed treatments

- problems with consistency, few available
- e.g. - *Bacillus subtilis* = Kodiak, HiStick N/T
  - *Burkholderia cepacia* = Deny
Efficacy of treatment with chlorine on eradication of seedborne inoculum of spinach leaf spot fungi

<table>
<thead>
<tr>
<th>% NaOCl</th>
<th>Duration in NaOCl (minutes)</th>
<th>Stemphylium (% of seed infected/infested)</th>
<th>Cladosporium (% of seed infected/infested)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2%</td>
<td>0.0</td>
<td>54.75</td>
<td>55.00</td>
</tr>
<tr>
<td></td>
<td>10.0</td>
<td>23.25</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>20.0</td>
<td>16.75</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>30.0</td>
<td>19.00</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>40.0</td>
<td>18.25</td>
<td>0.25</td>
</tr>
</tbody>
</table>
Disease management during harvest, storage & conditioning of seed

• adjustment & manipulation of equipment to remove pathogen structure from seed lots (sclerotia, teliospores, etc.)

• controlled storage conditions to avoid development of storage molds
Disease management practices in production crops

- cultural practices to minimize impact of seed- or soilborne pathogens
- seed treatments to minimize transmission of pathogens
- test seed to ensure infection levels lower than inoculum threshold that can cause disease
Criteria for development/use of inoculum thresholds for seedborne pathogens

- suitable seed health assay
- incidence of infection on seeds correlated with plant infection
- inoculum thresholds established by appropriate statistical analysis, e.g.:
  - \textit{X. campestris pv. campestris} of crucifers
  - \textit{X. campestris pv. carotae} on carrots in CA
  - \textit{lettuce mosaic virus}
Methods for seed health testing

- field inspections
- direct visual examination
- incubation
- grow-out
- indicator tests
- serological
- DNA hybridization

Reasons for seed health testing

- determine whether infection is below threshold
- for quarantine or phytosanitary certification
- to determine plant stand/health
Small-seeded vegetable seed crops
grown in semi-arid regions of the PNW

Umbelliferous seed crops
carrot, coriander, dill, parsley, parsnip, ...

Cruciferous seed crops
radish, daikon, turnip, kale, collard, kohlrabi, Chinese kale, Chinese mustard, ...

Allium seed crops
onion, leek, chives, ...

Others
Diseases of small-seeded vegetable seed crops

Umbelliferous seed crops

• bacterial blights
• *Alternaria* diseases: leaf blight, black rot
• powdery mildew
• phytoplasmas: aster yellows, BLTVA
• viruses: motley dwarf, BCTV, AMV, ...
• root knot nematode
• cavity spot, bacterial soft rot
Bacterial leaf blight
*Xanthomonas campestris pv. carotae*
Bacterial blight
*Xanthomonas campestris pv. carotae*
Alternaria leaf blight

*Alternaria dauci*

Howard et al. (1994)
carrot umbel infection by *Alternaria dauci*
Cercospora leaf spot
*Cercospora carotae*
Alternaria leaf blight
*Alternaria dauci*

Cercospora leaf spot
*Cercospora carotae*

Bacterial leaf blight
*Xanthomonas campestris pv. carotae*
Black rot
Alternaria radicina

Snowdon (1992)

Howard et al. (1994)
Host range

- *Xanthomonas campestris pv. carotae*
  - carrot
- *Alternaria dauci*
  - carrot, parsley, Umbelliferous weeds
- *Alternaria radicicna*
  - carrot, celery, parsley, parsnip, dill
- *Cercospora carotae*
  - carrot, other *Daucus* species
Incidence of plants on which *X. campestris* pv. *carotae* was detected in 14 carrot seed crops: WA, 2001/02
Population of *X. campestris* pv. *carotae* detected on stock seed & harvested seed of carrot seed crops: WA, 2001/02
Sampling debris/dust during threshing of seed crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Distance</th>
<th># samples</th>
<th>CFU/ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100’</td>
<td>10</td>
<td>13.30</td>
</tr>
<tr>
<td></td>
<td>150’</td>
<td>7</td>
<td>33.70</td>
</tr>
<tr>
<td></td>
<td>250’</td>
<td>3</td>
<td>1.80</td>
</tr>
<tr>
<td>2</td>
<td>25’</td>
<td>4</td>
<td>15.00</td>
</tr>
<tr>
<td></td>
<td>100’</td>
<td>12</td>
<td>10.40</td>
</tr>
<tr>
<td></td>
<td>150’</td>
<td>1</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>200’</td>
<td>8</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>300’</td>
<td>1</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>800</td>
<td>3</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>900’</td>
<td>8</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>~ 1 mile</td>
<td>5</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Management of bacterial blight in carrot seed crops

- pathogen-free seed or stecklings
- avoid overhead irrigation, where possible
- crop rotation
- plow or disc infested residues
- isolation from carrot root crops, seed crops
- copper applications, chlorine?, compost teas??
- hot water seed treatment @ 122°F for 30 min
- chlorine seed treatment (surface efficacy)
Management of Alternaria leaf blight in carrot seed crops

- disease-free seed & stecklings
- minimum 2-3 year crop rotation
- plow or disc infested residues
- fungicides
  - coppers
  - Bravo, Terranil (chlorothalonil)
  - Quadris
  - Rovral (foliar & seed treatment)
  - applications based on disease severity
  - new fungicides: Cabrio, Pristine, Folicur, …?
- seed treatments
  - thiram, Rovral, Maxim, hot water, chlorine
Management of black rot in carrot seed crops

- disease-free seed, stecklings
- 8+ year crop rotation
- plow or disc infested residues
- avoid overhead irrigation, where possible
- resistance
- fungicides
  - coppers
  - Rovral 4F (foliar, seed treatment)
  - new (Maxim, Quadris, Pristine, ...)
- seed treatments
  - hot water @ 122°F for 30 min
  - hot chlorine (0.1-1.0% @ 122°F for 30 min)
Powdery mildew

Erysiphe heraclei
Powdery mildew in carrot seed crops

- no yield loss if infection occurs > mid-June, otherwise seed yield/quality reduced
- remove wild/volunteer carrots
- isolate crops
- pathogen-free stecklings
- fungicides:
  - Kaligreen (potassium bicarbonate)
  - sulfurs (e.g., Kumulus DF, Microthiol Disperss)
  - Quadris F
  - AQ10 biofungicide (incompatible with some fungicides)
Phytoplasmas
Aster yellows & Beet leafhopper-transmitted virescence agent (BLTVA)
Aster yellows,
Beet leafhopper-
transmitted virescence agent
(BLTVA)
Phytoplasmas in seed crops

- leafhopper transmitted
- more prevalent after mild winters
- isolate from alternative & weedy hosts (?)

* Aster yellows/BLTVA: onion, Umbelliferous crops, Cruciferous crops, tomato, lettuce, many weeds, some ornamentals

- insecticides for leafhopper control
  - variable efficacy
  - timing relative to leafhopper migration
Beet curly top virus (BCTV)
beet leafhopper
Beet Curly Top Virus (BCTV) in seed crops

- beet leafhopper
- more prevalent after mild winters
- extensive host range
  - mustards, in perennial or winter annual weeds
- insecticides for leafhopper control
  - variable efficacy
  - timing relative to leafhopper migration
- resistance (?)
Diseases of small-seeded vegetable seed crops

*Allium seed crops*
- gray mold/scape blight/neck rot
- black mold
- bacterial soft rots
- Fusarium basal rot
- viruses ??
  - iris yellow spot virus = IYSV
Botrytis scape & flower blight

- *B. allii*
- *B. squamosa, B. cinerea, B. byssoida*
Seed-borne Botrytis
### 2001/02 survey of onion seed crops in WA

**Incidence (%) of plants infected with *Botrytis allii***

<table>
<thead>
<tr>
<th>Field &amp; irrigation</th>
<th>Plants sampled</th>
<th>Visual symptoms in the field</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9/01 11/01 4/02 6/02 7/02</td>
<td>9/01 11/01 4/02 6/02 7/02</td>
</tr>
<tr>
<td>A (spr)</td>
<td>5 5 15 100 100</td>
<td>0 0 0 0 7</td>
</tr>
<tr>
<td>B (spr)</td>
<td>3 0 - - -</td>
<td>0 0 - - -</td>
</tr>
<tr>
<td>C (furr)</td>
<td>15 3 70 100 100</td>
<td>0 0 0 0 16</td>
</tr>
<tr>
<td>D (furr)</td>
<td>8 10 95 100 100</td>
<td>0 0 2 5 10</td>
</tr>
<tr>
<td>E (furr)</td>
<td>63 0 70 100 100</td>
<td>0 0 0 2 10</td>
</tr>
<tr>
<td>F (furr)</td>
<td>8 3 25 100 100</td>
<td>0 0 1 6 7</td>
</tr>
<tr>
<td>G (furr)</td>
<td>18 3 30 95 100</td>
<td>0 0 0 2 4</td>
</tr>
<tr>
<td>H (spr)</td>
<td>- - 65 90 100</td>
<td>- - 0 0 17</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>19.6 3.2 52.9 97.9 100</td>
<td>0.0 0.0 0.4 2.1 8.7</td>
</tr>
</tbody>
</table>

*a* 20 or 40 plants sampled randomly per field

*b* 100 plants rated for symptoms of neck/bulb rot, scape/umbel blight

*c* Crop plowed under in 03/02

*d* Bulb-to-seed crop
2001/02 survey of 7 onion seed crops in WA
Incidence (%) of seed infected/infested with *Botrytis* spp.\(^a\)

<table>
<thead>
<tr>
<th>Field &amp; irrigation(^b)</th>
<th>Stock seed</th>
<th>Harvested seed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Internal(^c)</td>
<td>External(^c)</td>
</tr>
<tr>
<td></td>
<td><strong>B. allii</strong></td>
<td><strong>B. allii</strong></td>
</tr>
<tr>
<td>A (sprinkler)</td>
<td>F,M = 0.00</td>
<td>F,M = 0.75</td>
</tr>
<tr>
<td>B (sprinkler)</td>
<td>F,M = 0.00</td>
<td>-</td>
</tr>
<tr>
<td>C (furrow)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>D (furrow)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>E (furrow)</td>
<td>1.50</td>
<td>0.75</td>
</tr>
<tr>
<td>F (furrow)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>G (furrow)</td>
<td>3.00</td>
<td>6.75</td>
</tr>
<tr>
<td>H (sprinkler) bulb-to-seed</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>1.13</strong></td>
<td><strong>2.06</strong></td>
</tr>
</tbody>
</table>

\(^a\) 400 seed/field; F = female parent, M = male parent; - = seed unavailable
\(^b\) sprinkler = overhead irrigation
\(^c\) Internal = 60 sec. rinse in 0.5% NaOCl + triple H\(_2\)O rinse; External = 60 min. rinse in H\(_2\)O
Management of Botrytis in onion seed crops

- pathogen-free seed, treated seed
- fungicides
  - seed treatment (hot water, Thiram, Rovral, chlorine)
  - foliar sprays (e.g., Rovral, Bravo, Switch)
  - new fungicides (Serenade, Switch, Pristine, Endura, Botran, …)
- “healthy” crop
- sanitation (volunteers, culls, debris)
- rotation & isolation from other Allium crops
- well-dried umbels < harvest, artificial drying
Iris yellow spot virus
IYSV
Iris yellow spot virus (IYSV) in *Allium* seed crops

- onion thrips, not Western flower thrips
- not known to be seedborne, nor present in bulbs
- can cause significant yield losses (bulb & seed crops)
- range from symptomless to striking
- host range
  - onion, garlic, leek, chive, iris, *Nicotiana benthamiana* & *N. rustica*, *Datura stramonium*
- Brazil, Israel, Holland, US - western states
Diseases of small-seeded vegetable seed crops

Crucifer seed crops in semi-arid PNW

- viruses/BLTVA
- white rust
- powdery mildew
- Alternaria leaf/pod spot
- white mold
- damping-off/seedling blight fungi (*Rhizoctonia, Aphanomyces, Pythium*)
- black leg??
White rust of radish
*Albugo candida*
White rust of radish seed crops

- light green spots; white, raised blisters
- abnormal growth on seed stalk ("staghorn"); seed may not form
- seed yield & quality may be reduced severely
- select isolated fields
- host range
  - radish, rapeseed, mustards (including wild mustard)
  - control wild mustards
- resistance (some daikon cultivars)
- incorporate debris after harvest
- fungicides:
  - seed treatment - captan, thiram
  - at planting - Ridomil Gold
Root rots/damping off of Crucifer seed crops

*Aphanomyces, Pythium, Fusarium*

- blue-black lesions on roots
- constricted lesions, sometimes girdling
- discolored radial streaks
- general root rot, damping-off

- plant in well-drained soils, avoid overwatering
- > 3 year crop rotation
- fungicide treatment: e.g., Quadris in-furrow or banded
Small-seeded vegetable seed crops grown in the maritime coastal region of the PNW

Chenopodiaceous seed crops
  spinach, table beet, Swiss chard

Cruciferous seed crops
  cabbage, Brussels sprouts, cauliflower, Chinese cabbage, ...

Others
Spinach leaf spot fungi:

Cladosporium leaf spot
Stemphylium leaf spot
Anthracnose
Pleospora herbarum
= sexual stage of S. botryosum
Seedborne potential of leaf spot fungi

Conidiophores & conidia of *Cladosporium variabile* (top right & lower left) & a *Cladosporium* sp. (top left & lower right)

Pseudothecia of *Pleospora herbarum* & conidia of *Stemphylium botryosum*
Spinach anthracnose: *Colletotrichum dematium = C. spinaciae*

Photo by M.L. Derie
Spinach anthracnose:
Colletotrichum dematium = C. spinaciae

http://www.hgic.umd.edu/diagn/veg/anthracnose_fruit.html
Spinach anthracnose: 
*Colletotrichum dematium* = *C. spinaciae*
Spinach anthracnose: *Colletotrichum dematium*

- setae
- conidia
### Cladosporium leaf spot, Stemphylium leaf spot, & anthracnose of spinach

<table>
<thead>
<tr>
<th></th>
<th><strong>Cladosporium variable</strong></th>
<th><strong>Stemphylium botryosum</strong></th>
<th><strong>Colletotrichum dematium</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leaf spot symptoms</strong></td>
<td>Distinct, develop dark margin</td>
<td>Diffuse, rapidly expanding</td>
<td>Distinct, coalesce</td>
</tr>
<tr>
<td><strong>Spores in lesions</strong></td>
<td>+ (abundant in moist conditions)</td>
<td>+ (in moist conditions)</td>
<td>+ (in acervuli)</td>
</tr>
<tr>
<td><strong>Seedborne</strong></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>Dispersal</strong></td>
<td>Wind, seed</td>
<td>Wind, seed</td>
<td>Splashing water, seed</td>
</tr>
<tr>
<td><strong>Overwintering</strong></td>
<td>Volunteers, seed</td>
<td>Seed stalk debris, seed</td>
<td>Volunteers, seed</td>
</tr>
<tr>
<td><strong>Favorable conditions</strong></td>
<td>Moist, cool</td>
<td>Moist, warm, pollen</td>
<td>Wet, cool</td>
</tr>
<tr>
<td><strong>Host range</strong></td>
<td>&gt; Chenopods?</td>
<td>Spinach</td>
<td>Spinach</td>
</tr>
</tbody>
</table>

---

Foam spore dispersal

- **Volunteers, seed**
- **Wind, seed**
- **Dispersal**
- **Overwintering**
- **Favorable conditions**
- **Host range**

- **Moist, cool**
- **Moist, warm, pollen**
- **Wet, cool**
- **Spinach**
- > Chenopods?
Beet & chard leaf spot fungi:

- Phoma leaf spot
- Ramularia leaf spot
- Cercospora leaf spot
Phoma leaf spot of beets & chard: *Phoma betae*

Barnett & Hunter, 1972
Phoma leaf spot of beet/chard: *Phoma betae*

- **Pycnidia**
- **Holdfasts on water agar**
Ramularia leaf spot of beet & chard: *Ramularia betae*
Cercospora leaf spot of beet/chard: *Cercospora beticola*

Photos at NDSU website: http://www.ext.nodak.edu/extpubs/plantsci/rowcrops/pp1244w.htm
Cercospora leaf spot of beet/chard: *Cercospora beticola*

http://www.ext.nodak.edu/extpubs/plantsci/rowcrops/pp1244w.htm

*Cercospora conidia*
# Cercospora leaf spot, Ramularia leaf spot, and Phoma leaf spot of beets/chard

<table>
<thead>
<tr>
<th></th>
<th><strong>Cercospora beticola</strong></th>
<th><strong>Ramularia betae</strong></th>
<th><strong>Phoma betae</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symptoms</strong></td>
<td>Circular leaf spots, red-brown margin,</td>
<td>Light brown leaf spots, angular &amp;</td>
<td>Round leaf spots, concentric</td>
</tr>
<tr>
<td></td>
<td>older leaves;</td>
<td>larger, older leaves</td>
<td>rings on perimeter, dark margin;</td>
</tr>
<tr>
<td></td>
<td><strong>Crown lesions</strong></td>
<td></td>
<td><strong>Seedling black leg;</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Crown rot</strong></td>
</tr>
<tr>
<td><strong>Spores in leaf spots</strong></td>
<td>Minute black dots (stromata) in spots</td>
<td>Silvery gray to white in spots</td>
<td>Black pycnidia in leaf spots, on</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>crowns</td>
</tr>
<tr>
<td><strong>Seedborne</strong></td>
<td>+ (external)</td>
<td>+ (?)</td>
<td>+</td>
</tr>
<tr>
<td><strong>Dispersal</strong></td>
<td>Splashing water, wind, insects</td>
<td>Wind</td>
<td>Splashing water, insects</td>
</tr>
<tr>
<td><strong>Overwinter</strong></td>
<td>Weeds, debris</td>
<td>Debris</td>
<td>Soil, roots, debris, weeds</td>
</tr>
<tr>
<td><strong>Fav. conditions</strong></td>
<td><strong>Warm, moist</strong></td>
<td>Cool, moist</td>
<td><strong>Cool to warm, moist</strong></td>
</tr>
<tr>
<td><strong>Host range</strong></td>
<td>Beet, chard, Chenopod. weeds</td>
<td>Beet, chard</td>
<td>Beet, lambsquarter</td>
</tr>
</tbody>
</table>
Crucifer foliar pathogens:

- Alternaria leaf spot
- Ring spot
- Bacterial diseases
Alternaria leaf/pod spot of crucifers: 
*Alternaria brassicicola & A. brassicae*
Alternaria leaf/pod spot of crucifers

**Alternaria brassicicola**
smaller spores in chains, no beak

**Alternaria brassicae**
larger spores, not in chains, long beak

Photo from R.L. Gabrielson
Alternaria leaf/pod spot of crucifers:
*Alternaria brassicicola & A. brassicae*
Alternaria leaf/pod spot of crucifers:
*Alternaria brassicicola* & *A. brassicae*

chains of conidia of *A. brassicicola*
Ring spot of crucifers: *Mycosphaerella brassicicola*

Photos by L.J. du Toit

Photo from R.L. Gabrielson
Ring spot of crucifers: 
*Mycosphaerella brassicicola* 

Photo from R.L. Gabrielson
Ring spot of crucifers: *Mycosphaerella brassicicola*

sterile spermagonia & “conidia”

Drawings from CMI Descriptions of Pathogenic Fungi & Bacteria No. 468

perithecium with asci & ascospores

ascus & ascospores
Black leg of crucifers: *(Phoma lingam, sexual stage = Leptosphaeria maculans)*

- **conidia**
- **ascospores**
- **asci & ascospores**
- **perithecium with asci & ascospores**
- **pycnidium with conidia**

Drawings from CMI Descriptions of Pathogenic Fungi & Bacteria No. 331
# Alternaria leaf/pod spot & ring spot of crucifers

<table>
<thead>
<tr>
<th></th>
<th>Alternaria leaf/pod spot</th>
<th>Ring spot</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symptoms</strong></td>
<td>Black circular - irregular lesions; necrotic center; black spots on pods &amp; racemes</td>
<td>Circular lesions, definite margin &amp; chlorotic halo, concentric zonation; lowest leaves</td>
</tr>
<tr>
<td><strong>Spores in leaf spots</strong></td>
<td>Naked spores</td>
<td>Black pycnidia &amp;/or perithecia in concentric rings</td>
</tr>
<tr>
<td><strong>Seedborne</strong></td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td><strong>Dispersal</strong></td>
<td>Wind, insects</td>
<td>Splashing water, insects</td>
</tr>
<tr>
<td><strong>Overwinter</strong></td>
<td>Debris, biennial seed crops</td>
<td>Debris, biennial seed crops</td>
</tr>
<tr>
<td><strong>Favorable conditions</strong></td>
<td>Moist, warm</td>
<td>Moist, cool</td>
</tr>
<tr>
<td><strong>Host range</strong></td>
<td>Crucifers, beet</td>
<td>Crucifers</td>
</tr>
</tbody>
</table>
Black rot of crucifers: Xanthomonas campestris pv. campestris
Black rot of crucifers:  
*Xanthomonas campestris* pv. *campestris*
Black rot of crucifers: 

Xanthomonas campestris pv. campestris

Photos from R.L. Gabrielson
Xanthomonas leaf spot of crucifers: 
*Xanthomonas campestris* pv. *armoraciae/raphani*
Peppery leaf spot of crucifers: *Pseudomonas syringae* pv. *maculicola*

Photos from PetoSeed
**Xanthomonas campestris & Pseudomonas syringae pathogens of crucifers**

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Black rot</th>
<th>Xanthomonas leaf spot</th>
<th>Xanthomonas leaf spot</th>
<th>Peppery leaf spot</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pathogen</strong></td>
<td>X. c. pv. <em>campestris</em></td>
<td>X. c. pv. <em>raphani</em></td>
<td>X. c. pv. <em>armoraciae</em></td>
<td><em>P. s. pv. maculicola</em></td>
</tr>
<tr>
<td><strong>Symptoms</strong></td>
<td>Yellow leaves, wilting, black veins</td>
<td>Circular, water-soaked leaf spot, chlorotic halo; dark lesions on petioles</td>
<td>-</td>
<td>Circular to angular spots, chlorotic halo</td>
</tr>
<tr>
<td><strong>Systemic</strong></td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Seedborne</strong></td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Dispersal</strong></td>
<td>Splashing water, seed, insects</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Overwinter</strong></td>
<td>Debris, Crucifer weeds, soil</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Favorable conditions</strong></td>
<td>Warm to hot, wet</td>
<td>Cool to warm, extended wet periods</td>
<td>Cool to warm, extended wet periods</td>
<td>Cool, wet</td>
</tr>
<tr>
<td><strong>Host range</strong></td>
<td>Crucifers (including weeds)</td>
<td>Cabbage, broccoli, cauliflower, kale, radish, tomato, pepper</td>
<td>Cabbage, broccoli, cauliflower, kale, radish, horseradish</td>
<td>Cabbage, broccoli, cauliflower, Br. sprouts, turnip</td>
</tr>
</tbody>
</table>
Bacterial leaf spot of beet:
*Pseudomonas syringae* pv. *aptata*

Photos at http://www.ext.nodak.edu/extpubs/plantsci/rowcrops/pp1244w.htm
## Pseudomonas leaf spot diseases of spinach & beet

<table>
<thead>
<tr>
<th></th>
<th>P. syringae pv. spinaciae</th>
<th>P. syringae pv. aptata</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symptoms</strong></td>
<td>Irregular, water-soaked spots; older lesions dark brown to black, angular; lesions visible from top &amp; bottom of leaf</td>
<td>Circular to irregular leaf spots, tan center, dark margin; leaf margins; coalesce to ragged appearance</td>
</tr>
<tr>
<td><strong>Seedborne</strong></td>
<td>- (?)</td>
<td>+</td>
</tr>
<tr>
<td><strong>Dispersal</strong></td>
<td>Splashing water, machinery</td>
<td>Splashing water, insects, machinery</td>
</tr>
<tr>
<td><strong>Overwinter</strong></td>
<td>Debris?</td>
<td>Debris,</td>
</tr>
<tr>
<td><strong>Favorable conditions</strong></td>
<td>Wet, cool?</td>
<td>Wet, <strong>cool</strong></td>
</tr>
<tr>
<td><strong>Host range</strong></td>
<td>Spinach, others?</td>
<td>Beet, chard, bean, eggplant, lettuce, and pepper</td>
</tr>
</tbody>
</table>
White mold: *Sclerotinia sclerotiorum*
sclerotium & apothecium
asci with ascospores

ascospores
**Sclerotinia sclerotiorum**

- extremely broad host range
  (p. 27 of “2003 PNW Disease Mngmt Hdbk”)
- long-lived (sclerotia)
- favorable conditions:
  - extended periods of moist conditions
  - high humidity - dense canopy, rain, irrigation, dew
  - cool or warm temperatures
Wilt diseases:

*Fusarium oxysporum* & *Verticillium dahliae*
Wilt diseases: *Fusarium oxysporum* vs. *Verticillium*

<table>
<thead>
<tr>
<th></th>
<th><em>F. oxysporum</em></th>
<th><em>Verticillium</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Soilborne</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Seedborne</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Host range</td>
<td>Narrow (specific)</td>
<td>Broad</td>
</tr>
<tr>
<td>Survival in soil</td>
<td>Long-term</td>
<td>Long(er)-term</td>
</tr>
<tr>
<td>Favorable conditions for infection/symptoms</td>
<td>Warm, “dry”</td>
<td>Warm, “dry”</td>
</tr>
</tbody>
</table>
## Wilt diseases: *Fusarium oxysporum*

<table>
<thead>
<tr>
<th><em>Forma specialis</em></th>
<th>Symptomatic host</th>
<th>Asymptomatic host</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>F. oxysporum</em> f. sp. <em>spinaciae</em></td>
<td>Spinach</td>
<td>Beet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Swiss chard</td>
</tr>
<tr>
<td><em>F. oxysporum</em> f. sp. <em>betae</em></td>
<td>Beet, Swiss chard</td>
<td>Spinach</td>
</tr>
<tr>
<td><em>F. oxysporum</em> f. sp. <em>conglutinans</em></td>
<td>Cabbage (strains 1 &amp; 5) Brussels sprout, cauliflower, collard, kale, mustards, rape, rutabaga, ... (strain 1) Flowering stock (strains 3 &amp; 4)</td>
<td></td>
</tr>
<tr>
<td><em>F. oxysporum</em> f. sp. <em>raphani</em></td>
<td>Radish (formerly strain 2 of <em>F. oxysporum</em> f. sp. <em>conglutinans</em>)</td>
<td></td>
</tr>
</tbody>
</table>
Fusarium wilt of radish: *F. oxysporum f. sp. raphani*
Fusarium wilt of radish: 
*F. oxysporum f. sp. raphani*
Fusarium wilt of radish: 
*F. oxysporum* f. sp. *raphani*

Photo by D.A. Inglis
Fusarium wilt of spinach: 
*F. oxysporum f. sp. spinacea*
Fusarium wilt of spinach: 
*F. oxysporum f. sp. spinaciae*
Verticillium wilt vs. Fusarium wilt of spinach

Verticillium wilt

Fusarium wilt
Verticillium wilt vs. Fusarium wilt of spinach

Verticillium wilt

Fusarium wilt
Fusarium wilt  Verticillium wilt  Control
Systemic infection by *Verticillium*

Non-inoculated control

Inoculated with *V. dahliae*
Verticillium wilt vs. Fusarium wilt of spinach
Verticillium wilt of spinach
Spinach wilt:  
*Fusarium oxysporum* vs. *Verticillium dahliae*

<table>
<thead>
<tr>
<th></th>
<th><strong>Fusarium wilt</strong></th>
<th><strong>Verticillium wilt</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptoms</td>
<td>Any stage in development</td>
<td>Only after bolting &amp; initiation of seed set</td>
</tr>
<tr>
<td>Foliar symptoms</td>
<td>General wilting, flaccid, off-green, death</td>
<td>Oldest leaves 1st. initial interveinal chlorosis, then necrosis</td>
</tr>
<tr>
<td>Reddening of stem</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>External root</td>
<td>Black</td>
<td>None/Light brown</td>
</tr>
<tr>
<td>discoloration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vascular discoloration</td>
<td>Black</td>
<td>Light brown</td>
</tr>
<tr>
<td>Seedborne/transmitted</td>
<td>+/+</td>
<td>+/+</td>
</tr>
<tr>
<td>Host range</td>
<td><em>Chenopodiaceae</em></td>
<td>Broad</td>
</tr>
<tr>
<td>Host resistance</td>
<td>+</td>
<td>?</td>
</tr>
</tbody>
</table>
Verticillium wilt: *Verticillium dahliae* & *V. albo-atrum*

**Crucifer hosts:**
- **Susceptible** = cauliflower, Brussels sprouts, cabbage
- **Resistant** = broccoli, mustards

**Chenopod. hosts:**
- Spinach, beets, chard

**Other hosts:**
- Numerous! Dependant on vegetative compatibility group (VCG)
Virus diseases of Chenopodiaceous & Cruciferous vegetables
Tools & techniques for diagnosis of virus diseases

- symptoms
- signs
  - virus inclusion bodies - light microscopy
  - virions - electron microscopy
- host range studies
- vector transmission evaluations
- local lesion assays
- biochemical/physical tests
- immunological assays - ELISA, immunogold labeling, ...
- molecular (DNA or RNA) assays - PCR
Virus diseases of Crucifers: 
*Turnip mosaic virus* (TuMV)
Virus diseases of Crucifers: *Cauliflower mosaic virus (CaMV)*
## Viruses diseases of Crucifers: CaMV vs. TuMV

<table>
<thead>
<tr>
<th></th>
<th>CaMV</th>
<th>TuMV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symptoms</strong></td>
<td>Mosaic, veinal chlorosis, leaf distortion, premature flowering</td>
<td>Black necrotic ring spots; mosaic, leaf distortion, necrosis</td>
</tr>
<tr>
<td><strong>Vector</strong></td>
<td>Several aphids: e.g., green peach aphid, cabbage aphid</td>
<td></td>
</tr>
<tr>
<td><strong>Transmission</strong></td>
<td>Non-persistent</td>
<td></td>
</tr>
<tr>
<td><strong>Seedborne</strong></td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Survival</strong></td>
<td></td>
<td>Cruciferous weeds</td>
</tr>
<tr>
<td><strong>Host range</strong></td>
<td>Crucifers only</td>
<td>Crucifers, lettuce, endive, spinach, zinnia, petunia, ...</td>
</tr>
</tbody>
</table>
Virus diseases of spinach:
*Cucumber mosaic virus (CMV)*
Virus diseases of spinach: 

*Cucumber mosaic virus (CMV)*

- crown leaves narrow, curled, wrinkled, margins roll in
- leaves yellow and die
- stunting
- symptoms develop faster at high temperatures
- aphid transmitted
- overwinters in perennial weeds, builds up in vegetables (especially cucurbits)
- spread by many aphids
# Virus yellows of beet

<table>
<thead>
<tr>
<th>Virus</th>
<th>Name</th>
<th>Host Range</th>
<th>Sheph. Purse</th>
<th>Chenop. capitatum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Closterovirus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BYV</td>
<td>Beet Yellows Virus</td>
<td>narrow</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td><strong>Luteovirus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BWYV</td>
<td>Beet Western Yellows Virus</td>
<td>wide</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>BChV</td>
<td>Beet Chlorosis Virus</td>
<td>narrow</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>BMYV</td>
<td>Beet Mild Yellows Virus</td>
<td>intermed.</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Table provided by R.T. Lewellen, USDA ARS, Salinas, CA
Virus diseases of beet & chard:

Beet western yellows virus (BWYV)
Virus diseases of beet & chard: *Beet yellows virus (BYV)*

Photos provided by R.T. Lewellen
Virus diseases of beet & chard: *Beet mosaic virus (BMV)*

# Important aphid-borne viruses of beets: BWYV, BYV, BMV

<table>
<thead>
<tr>
<th></th>
<th>BWYV</th>
<th>BYV</th>
<th>BMV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symptoms</strong></td>
<td>Interveinal yellowing <em>(older leaves first)</em>; red-brown spots between veins (bronze cast); thick, leathery, brittle leaves; poor root growth</td>
<td>Yellow circular spots <em>(young leaves)</em>; puckered leaves with mottling; stunting</td>
<td></td>
</tr>
<tr>
<td><strong>Vector</strong></td>
<td>Aphids (many)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Transmission</strong></td>
<td>Persistent</td>
<td>Semi-persistent</td>
<td>Non-persistent</td>
</tr>
<tr>
<td><strong>Seedborne</strong></td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Survival</strong></td>
<td>Alternative crop &amp; weed hosts</td>
<td>Alternative hosts</td>
<td>Overwintering seed crops, weed hosts</td>
</tr>
<tr>
<td><strong>Host range</strong></td>
<td>Very broad</td>
<td>Mainly Chenopodiaceae</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
Virus diseases of beet & chard: Rhizomania

Beet necrotic yellow vein virus (BNYVV) & soilborne fungus Polymyxa betae

Photos provided by R.T. Lewellen
Virus diseases of beet & chard: 
Rhizomania

Photos provided by R.T. Lewellen
Virus diseases of beet & chard: Rhizomania

- root stunting, proliferation, vascular discoloration
- upright, yellow leaves, proliferation of leaves
- distinct veinal yellowing is rare but diagnostic
- wilting in higher temperatures

- vectored by the soilborne fungus, Polymyxa betae
- vector favored by saturated soils
- spreads in infected soil, on plants
- vector survives in soils >10 years
- potential yield loss is high

- found in sugarbeet fields along Columbia River in 2000
- concern re. table beet seed industry in PNW
Some other viruses of spinach, beet & chard

**Beet curly top virus (BCTV)**
- beet leafhopper vector
- very broad host range
- stunting, hairy roots, thickened & rolled leaves

**Beet chlorosis virus (BChV)**
- non-persistent aphid vector
- interveinal yellowing

Photos provided by R.T. Lewellen
Monitoring diseases

- appearance/development
- threshold populations
- need for control
- effectiveness of actions