Disease Management in Carrot Production in the Pacific Northwest

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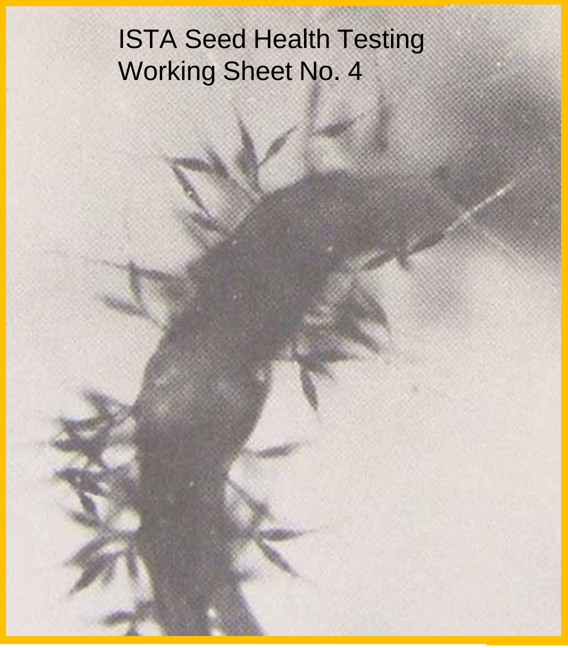
Bacterial blight

Xanthomonas hortorum* pv. *carotae

Cercospora leaf spot

Cercospora carotae

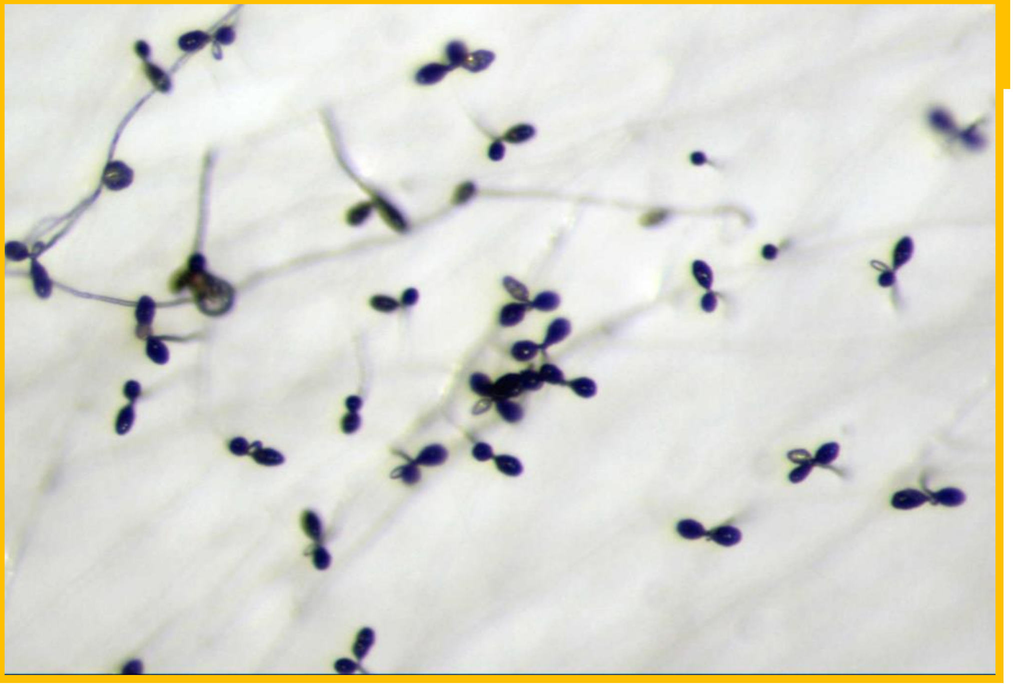


Alternaria leaf blight

Alternaria dauci

Black rot

Alternaria radicina



Survival & spread

- ***Xanthomonas campestris* pv. *carotae***
  - seed (internal & external)
  - infested residues in soil (1 year)
  - splashing water, insects, seed
- ***Cercospora carotae***
  - infested residues, wild carrot, other *Daucus* species
  - wind, splashing water, farm machinery, workers
- ***Alternaria dauci***
  - seed (internal & external)
  - infested crop residues, Umbelliferous weed hosts
  - wind, splashing water, farm machinery, workers, seed
- ***Alternaria radicina***
  - seed (internal & external)
  - soil (>8 years), infested residues on soil surface
  - movement of soil, roots, seed; splashing water

Conditions favoring pathogens

- *Xanthomonas campestris* pv. *carotae*
  - warm, wet conditions
  - 77-86ºF optimal (55-100ºF, killed at 120ºF)
  - 10-12 day disease cycle
- *Cercospora carotae*
  - cool to warm, wet conditions
  - 68-86ºF optimal, >12 hours leaf wetness
  - ~10 day disease cycle
- *Alternaria dauci*
  - moderate-warm, wet conditions
  - 84ºF optimal (57-95ºF)
  - 8-16 day disease cycle
- *Alternaria radicina*
  - cool to warm, wet
  - 84ºF optimal (31-93ºF)
  - storage >92% RH
  - "monocyclic" root infection; "polycyclic" foliar infection

Management of bacterial blight

- Pathogen-free or hot water-treated seed (122ºF, 25 min)
- 2– to 3-year crop rotation
- Incorporate infested residues
- Resistance? e.g., Danvers
- Bactericide applications:
  - Coppers, ManKocide
  - <u>Preventative only</u>
  - Thorough coverage
  - Repeat applications

Management of Cercospora leaf spot

- 2- to 3-year crop rotation
- Incorporate crop residues
- Time irrigation so tops are dry at night
- Spartan cultivars resistant, e.g., Delite, Delux, Fancy, Bonus, Classic, Winner, Premium
- Fungicides:
  - coppers, Bravo, strobilurins, …
  - prediction for sprays (Canada)
  - thorough coverage

Management of Alternaria leaf blight

- **Pathogen-free or treated seed**
- **2- to 3-year crop rotation**
- **Incorporate infested carrot residues in fall**
- **Avoid excessive nitrogen fertility**
- **Partially resistant cultivars**
- **Fungicides:**

- coppers
- chlorothalonil
- strobilurins, fludioxonil, etc.
- timing applications, good coverage

- **Gibberellic acid** (Santos et al. 2000)
- **Seed treatments:**

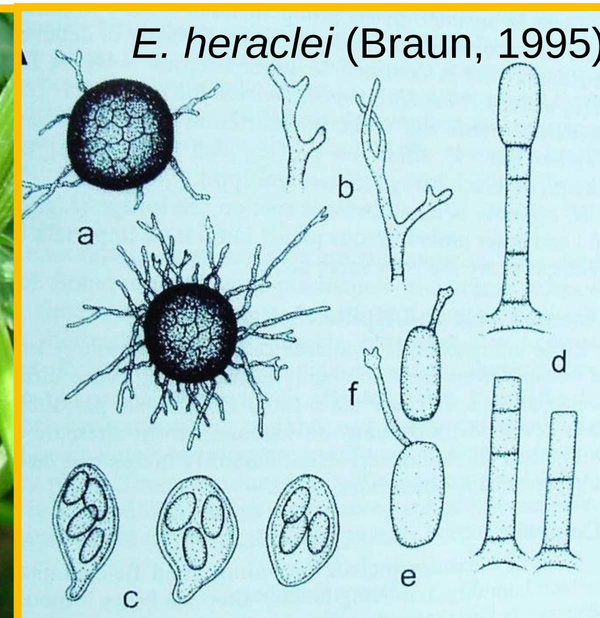
- Maxim, Rovral, Quadris, hot water

Management of black rot

- Pathogen-free or treated seed, stecklings
- 8+ year crop rotation
- Incorporate infested carrot residues
- Irrigate so carrots dry by nightfall
- Discard infected roots before storage
- Storage: 32ºF & 92% RH if infested
- Resistant cultivars?
- Fungicides:
  - Coppers, strobilurins, iprodione (Rovral), …
- Seed treatments:
  - fungicides, e.g., Rovral, Maxim, Quadris, …
  – hot water @ 122ºF for 30 min
  - hot sodium chloride (0.1-1.0%, 122ºF 30 m)

Carrot powdery mildew

Erysiphe heraclei, Leveillula taurica



Management of powdery mildew

- Crop rotation
- Incorporate infested residues in fall
- Overhead irrigation
- Plant spacing/row orientation
- Avoid excessive nitrogen fertilization
- Avoid crop stress
- Resistance
- Fungicides:
  - many choices, thorough coverage, resistance management

Phytoplasmas/spiroplasmas

Aster yellows, BLTVA, purple leaf


A
B
C
D

Phytoplasmas & spiroplasmas

- Broad host range
- Vectors: aster & beet leafhoppers, etc.
- Causal agents:
    - aster yellows phytoplasma (16SrI)
    - clover proliferation (16SrVI) = BLTVA
    - *Spiroplasma citri*
- Management:
    - remove infected weeds/carrots
    - avoid planting near symptomatic crops
    - leafhopper control, e.g., Admire, Provado, Lannate, Actara, Mustang, …
    - resistant cultivars
    - “Aster Yellows Index” (Midwest)
        - leafhopper testing + carrot cv. susceptibility

Pathogen distribution in beet leafhoppers and in vegetable/seed crops

A small plot study

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Plant Pathologist
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Gina Angelella
Research Entomologist
USDA-ARS
Wapato, WA

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Research Entomologist
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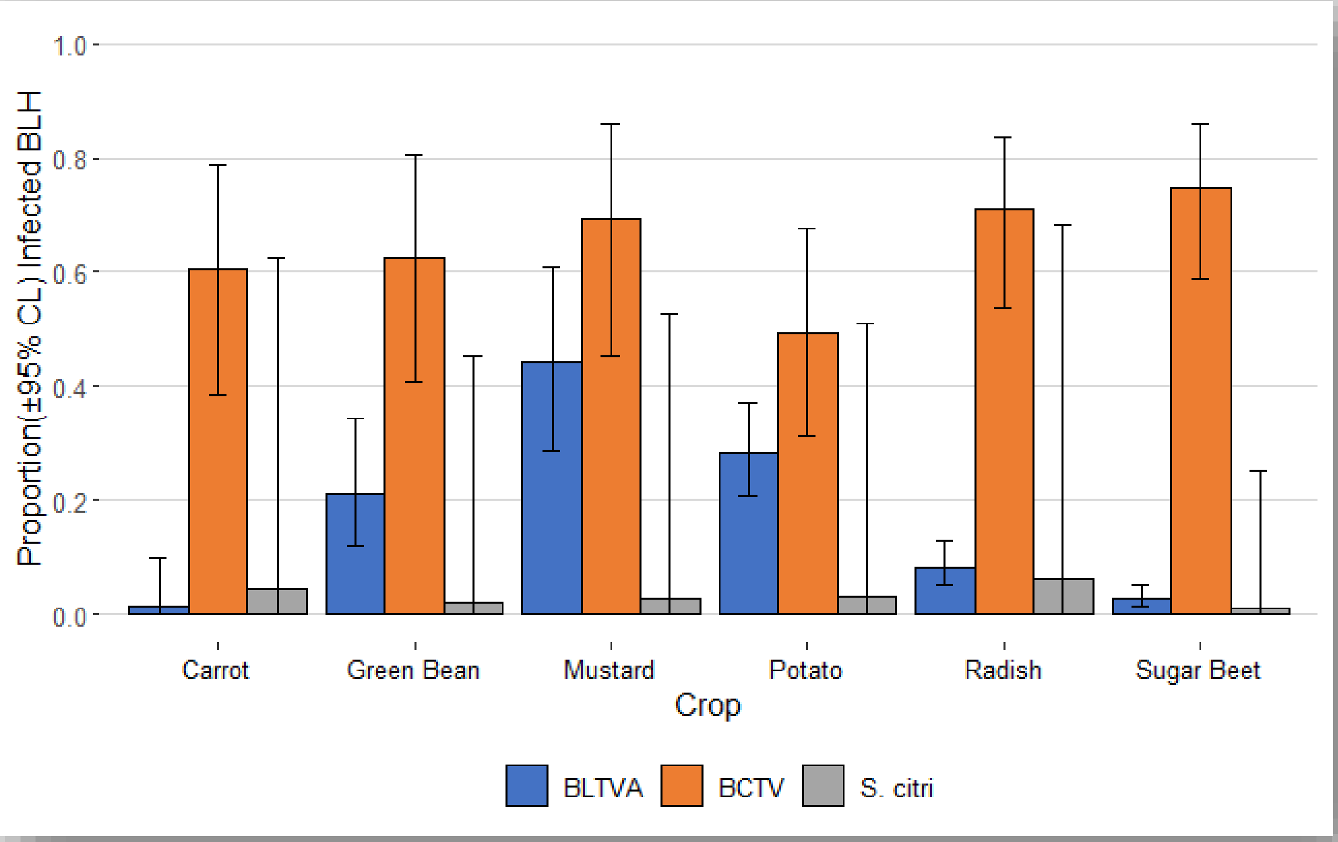
2021 USDA-ARS Research Trial

- Six crops planted in a randomized complete block design
  - Potato
  - Green bean
  - Sugar beet
  - Radish
  - **Carrot**
  - Mustard
- Beet leafhoppers and plant tissue collected bi-weekly
- Samples tested for BLTVA, BCTV, and *Spiroplasma citri*

Pathogen Rates

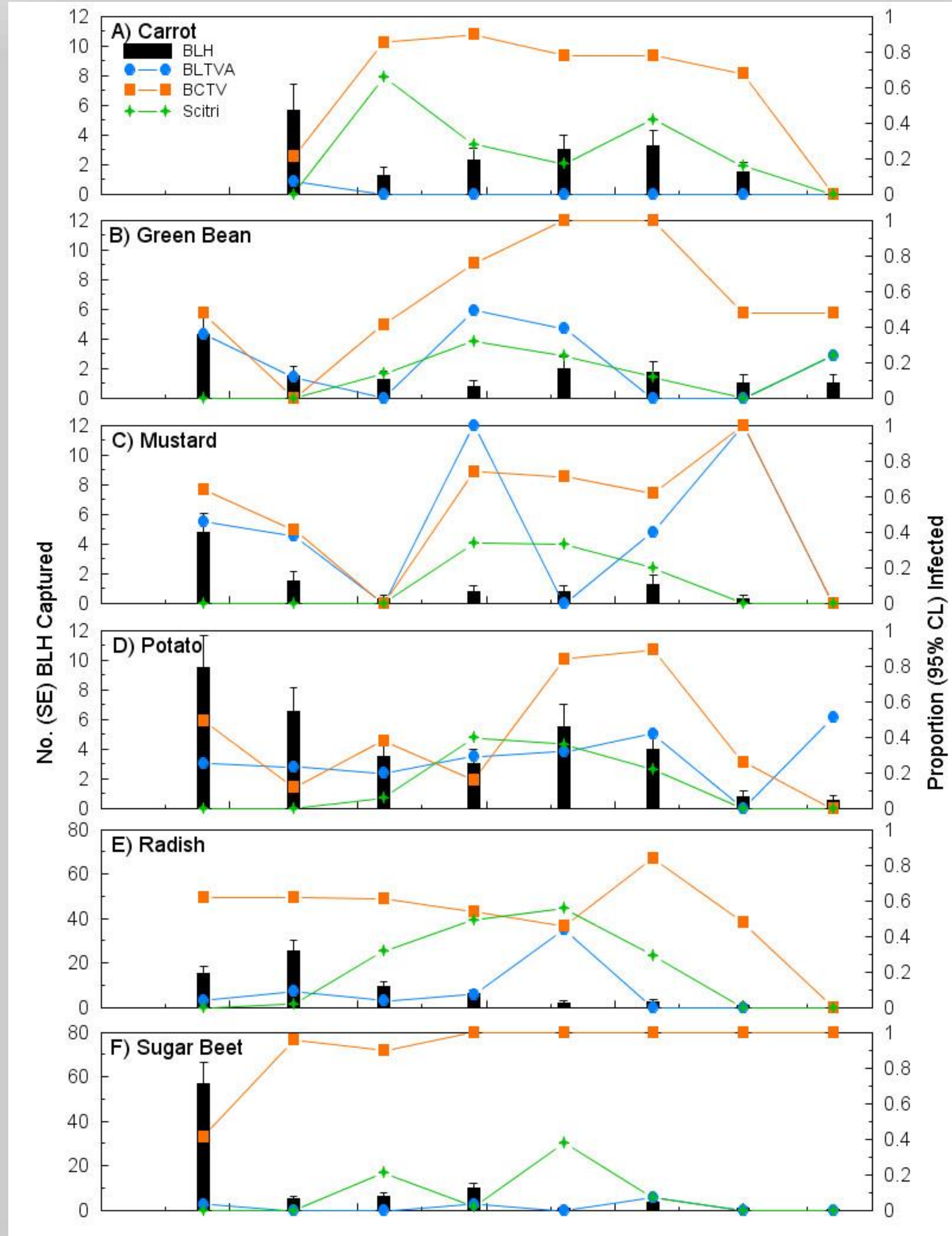
- BCTV rates were the highest in BLHs
- BLTVA rates in BLHs were variable among plant species
- *S. citri* rates were lowest in BLHs



Pathogen distribution over time

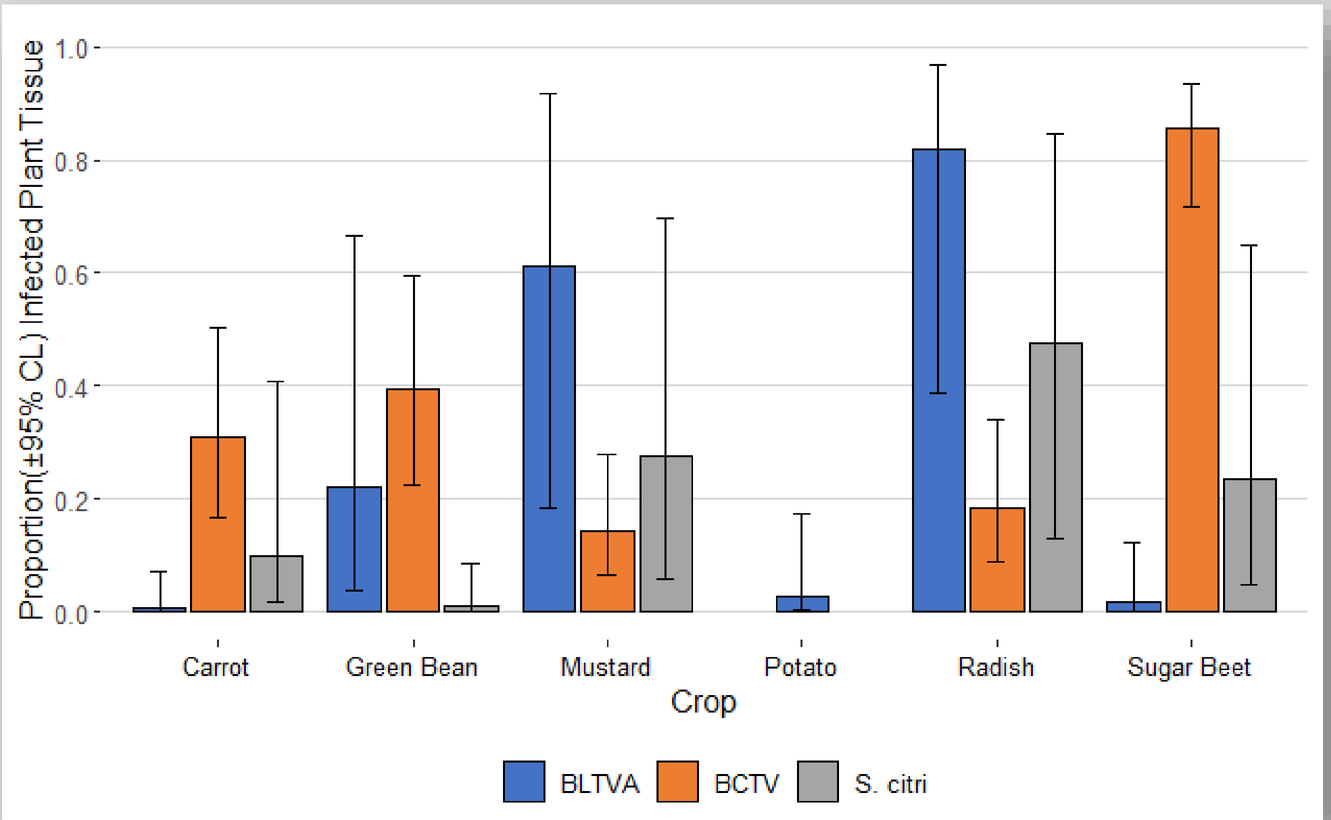
- Highest number of BLHs collected in radish and sugar beet
- *S. citri* levels consistently low and BCTV levels consistently high

  (Consistent with BLHs collected near commercial vegetable/seed fields across Columbia Basin of WA)
- BLTVA-infected BLHs start in mustard and disperse to other crops



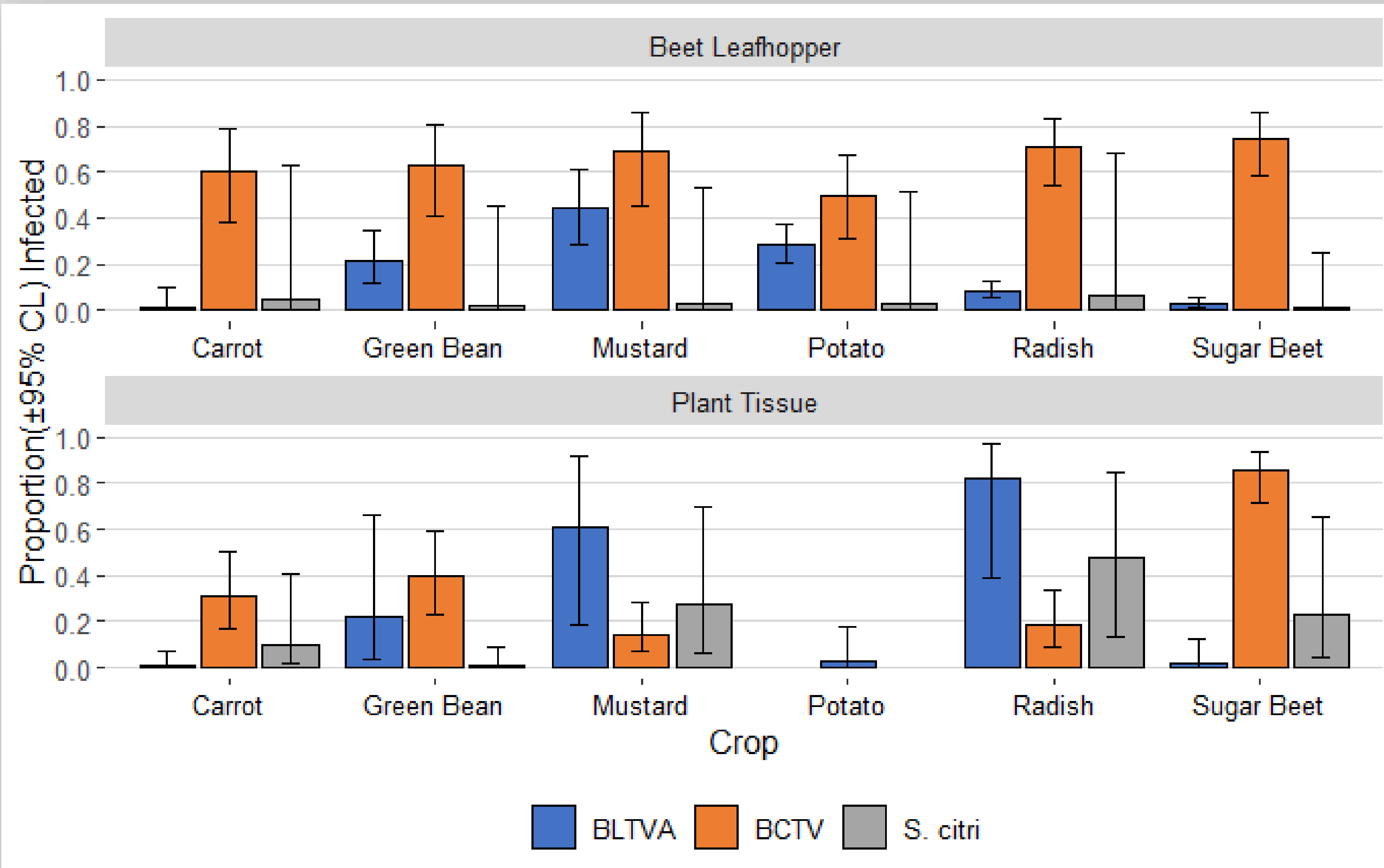
Pathogen Rates

- Pathogen prevalence varied among plant species



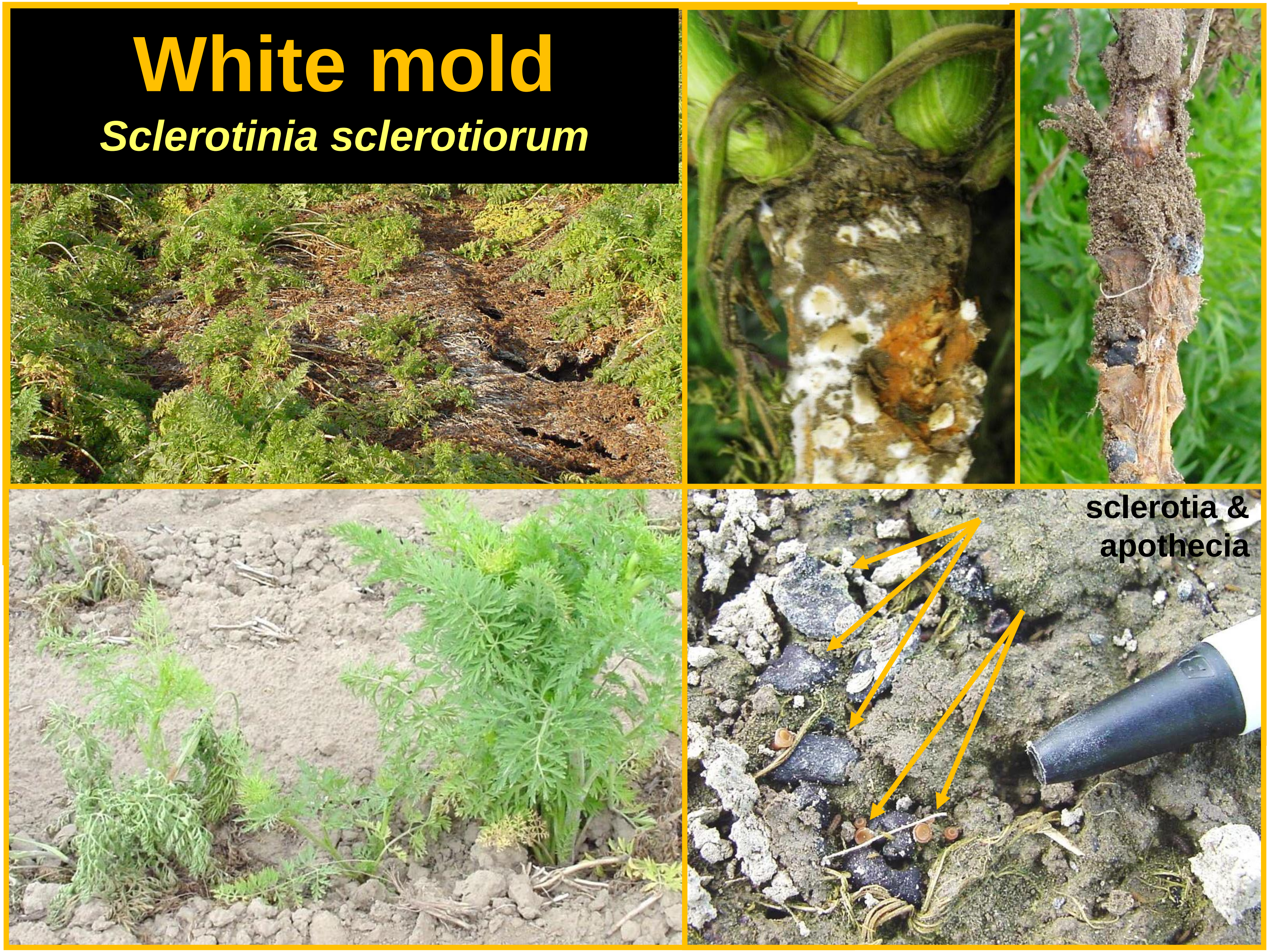
Comparison of BLH & plant pathogen prevalence

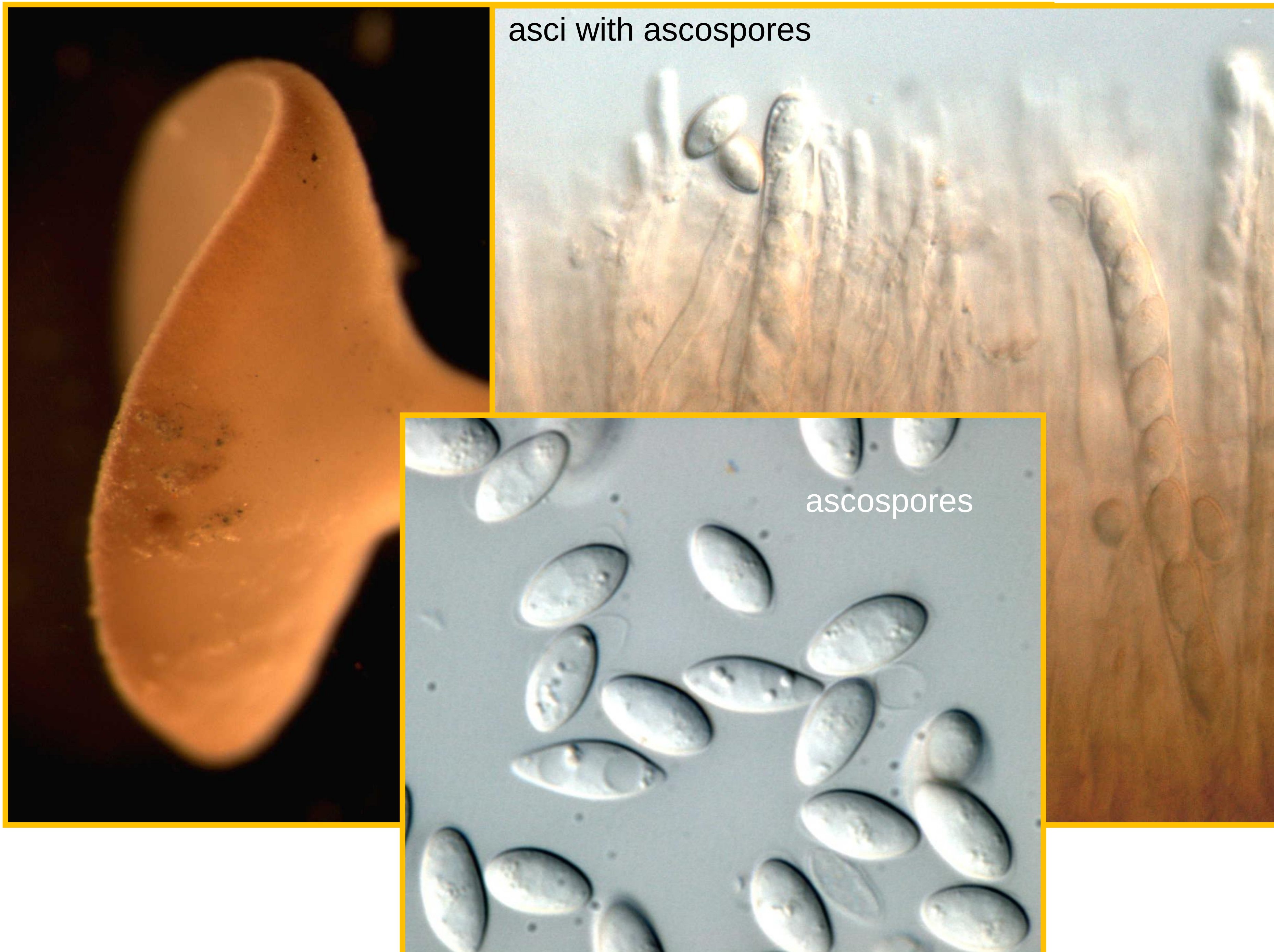
- Pathogen distribution in BLHs and plant tissue not consistent across 6 plant species
- Transmission rates of each pathogen likely differ among affected crops



Pathogen distribution in beet leafhoppers and vegetable/seed crops

- Repeat experiment in 2022 failed due to weed pressure
- 2023 repeat trial, in process of testing BLHs and plant samples


White mold
Sclerotinia sclerotiorum
sclerotia &
apothecia


asci with ascospores
ascospores

White mold

- Broad host range, persistent sclerotia
- Sclerotial germination: apothecia or mycelium
- Apothecia release ascospores aerially – foliar infections
- Favorable conditions: extended moisture, humidity
- Management:
  - rotation (non-host crops, e.g., cereals)
  - row orientation
  - trim canopy (increase air circulation)
  - irrigation management (keep top of bed dry)
  - flooding
  - broccoli, green manure crops
  - fungicides:
    - Contans (*Coniothyrium minitans*) colonizes sclerotia
    - foliar applications (boscalid, fluazinam, iprodione, thiophanate-methyl, …)
    - timing, coverage, resistance management

Root knot nematode

Meloidogyne hapla, other species

Root knot nematodes

- Infect many other crops
- Worse on sandy soils, optimum development at 60-77^{o}F
- 1-3 generations/season
- Low tolerance: 2 juveniles of *M. hapla*/100 cm^3 soil in WA
- Management:
  - test soil before planting (fall), roots + soil
  - early planting (cool soils)
  - rotate with non-host crops (corn, cereals)
  - avoid irrigating from ponds that drain infected fields
  - resistant cultivars needed, breeding in progress
    - Phil Simon, Phil Berger, USDA ARS
  - soil fumigation:
    - Vapam pre-plant
    - Vydate in-furrow at planting or chemigated post-planting/pre-emergence + subsequent applications

Carrot Improvement for Organic Agriculture: Leveraging On-Farm and Below Ground Networks

(2021-2025) Phil Simon, Phil Roberts, et al., USDA OREI

1: Cultivar & breeding population development & release

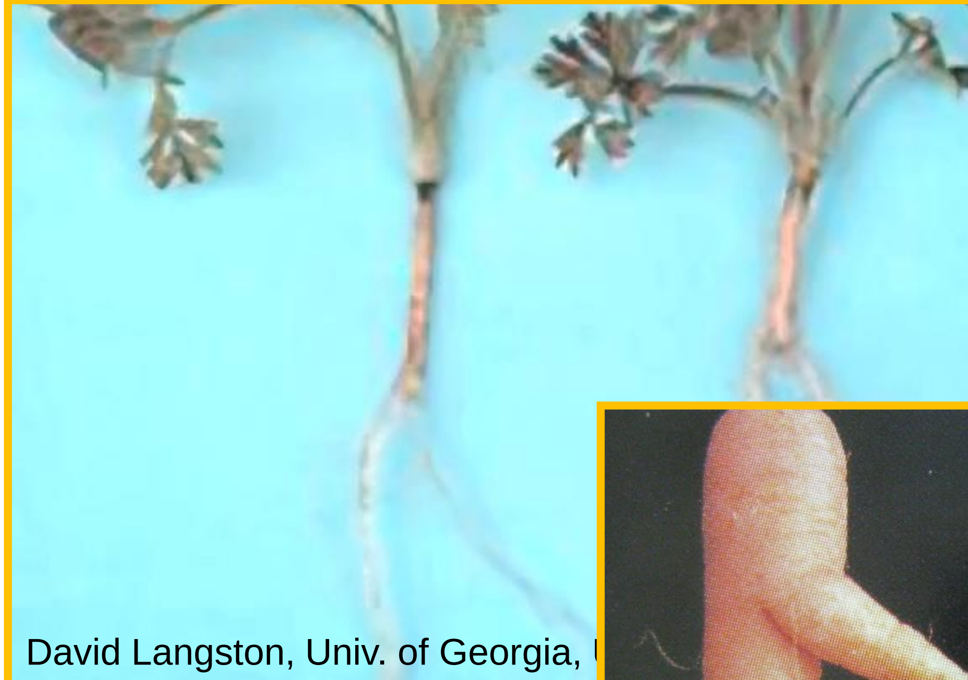
2: Participatory variety trial &plant breeding network
3: Links between microbiomes, nutrient uptake, pathogen resistance, & root nutritional quality & storability
4: Molecular markers to improve nematode resistance
5: Evaluate &improve carrot flavor, texture, &color

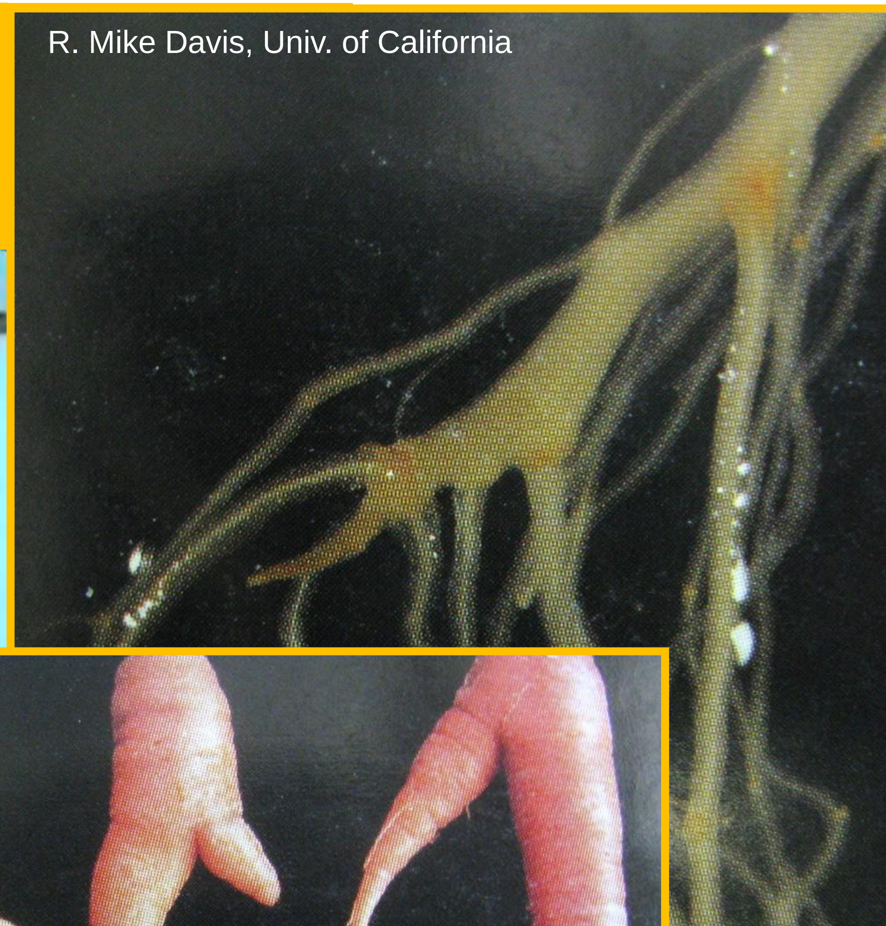
6: Evaluate nematode resistance

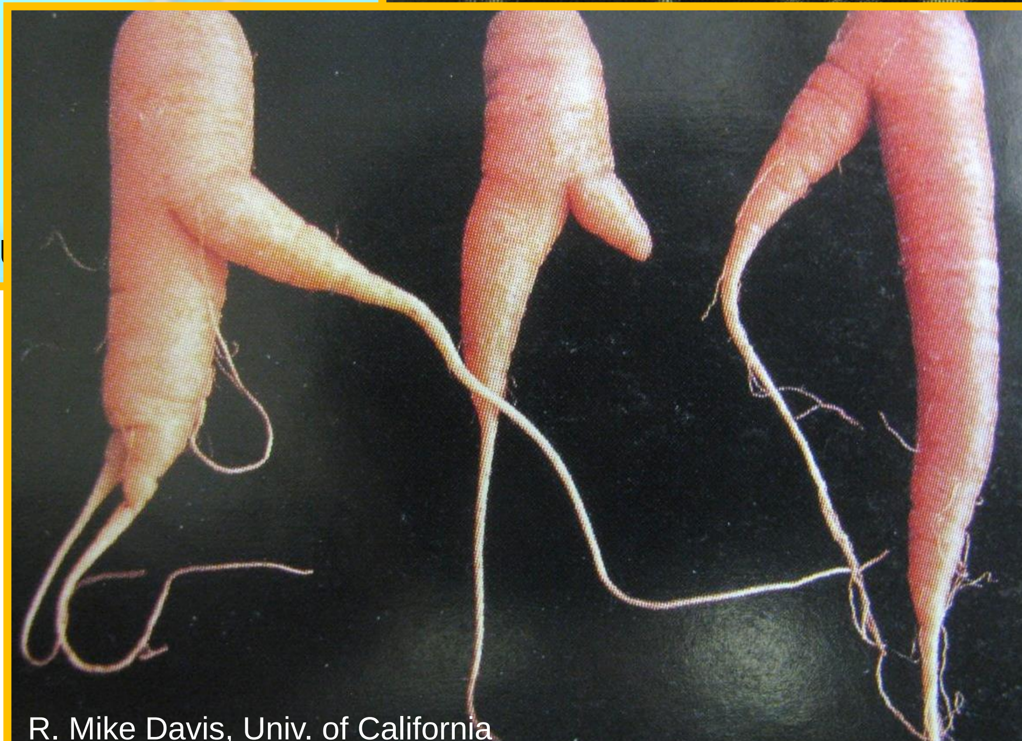
WA Role (Tim Waters): PIs planted each year at nematode nursery at WSU Othello research farm, collaboration with Phil Roberts (University of CA). Plots have root knot nematode that impacts carrot production in Columbia Basin. Carrot roots harvested, washed, evaluated for nematode damage and Brix measurements. Roots with best resistance shipped to Phil Simon in WI for evaluation, vernalization, and crossing.

Pythium
diseases
Cavity spot

Pythium diseases
Root tip dieback

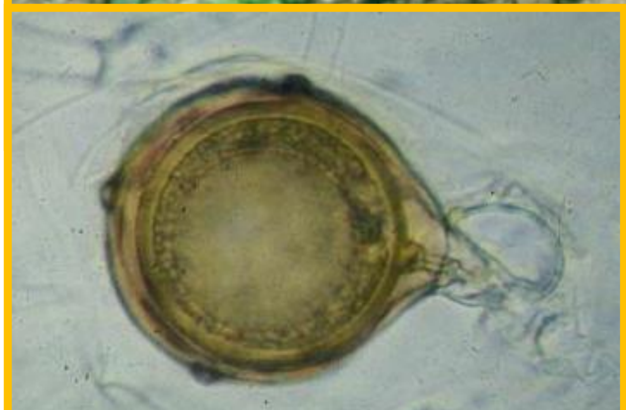

David Langston, Univ. of Georgia, U


R. Mike Davis, Univ. of California


R. Mike Davis, Univ. of California

Damping-off

Pythium, Rhizoctonia, Fusarium



Management of carrot damping-off

Cultural practices

- Test soil for damping-off risk?
  - Measuring total *Pythium* or particular species did NOT work (Howard et al., 1975; Liddell et al., 1989)
  - Soil grow-out for *R. solani* predicted incidence in fields (Shlevin & Katan, 1975) – avoid fungicides in 'clean' fields
- Soil flooding, e.g., Strandberg (1985):
  - Florida: short-term benefit
  - More effective at 25-30^{o}C than 15-20^{o}C
- Crop rotation
  - Green manure/biofumigant crops
  - Cash crops – broad host range of pathogens

  Davis & Nunez (1999), CA: alfalfa exacerbated, barley/cotton increased forking/stubbing some years, small grains reduced damping-off, interval between cover crop & carrot

Management of carrot damping-off

Chemical practices

- Conventional fungicides
  - *Pythium*–specific: e.g., metalaxyl or mefenoxam, **fenamidone (Reason), cyazofamid (Ranman), fluopicolide (Presidio)**
    - Seed treatments, drenches
    - Biodegradation in sandy soils, resistance
  - *Rhizoctonia*-specific: e.g., PCNB, strobilurins
    - Less effective as seed treatment vs. drenches or banded/incorporated
  - *Fusarium*-specific: e.g., fludioxonil, thiabendazole
- Soil fumigation: e.g., metam sodium
  - Biological fungicides: Efficacy? Diverse environments

WSU Carrot Cavity Spot Nursery

(since 2019, Mount Vernon, WA)

Lindsey du Toit, Tim Waters, & Michael Derie
Washington State University
Phil Simon, USDA ARS
Mary Ruth McDonald, University of Guelph

USDA NIFA SCRI Project No. 2016-51181-25400
USDA NIFA SCRI Project No. 2021-51181-38321

WSU Carrot Cavity Spot Nursery

2016-2021 Carrot SCRI I Project:

- **Fall 2018:** Metam sodium fumigation of 0.5 ha at WSU Mount Vernon NWREC
- **Inoculated field with *Pythium violae & P. sulcatum*:** Fall 2018, spring & fall 2019, spring 2020, 2021, 2022
- **Rated:** Incidence & severity of cavity spot, rust fly, forking, split roots
- **2019:** 223 USDA breeding lines/PI's + 12 cultivars (2-4 reps)
  - Least cavity spot PI 225869, PI 225870, PI 652188, PI 451761, & 725-1
- **2020:** 58 breeding lines + 13 cultivars (3 reps)
  - 2 with less cavity spot than Purple Haze: CS044 & CS002
  - 4 with less cavity spot than Propeel: CS003, CS027, CS049, & CS031
- **2021:** 72 breeding lines + 13 cultivars (3 reps)
  - 4 with less cavity spot than Purple Haze: CS107, CS147, CS150, CS165
  - + 12 with less cavity spot than Propeel
  - Included lines with NbH2306B, F7737B, R5646B, or W7308B in genetic background
  - **Comparison:** Muck cavity spot nursery in Ontario, Canada

2022-2026 Carrot SCRI II Project:

- **2023:** Inoculated cavity spot nursery, planted 78 breeding lines & cultivars in 3 reps (10 May), roots to be harvested & rated, roots selected for crossings by Phil Simon
- **2024-2026:** Continue screening USDA PI collection, breeding lines, & crosses to develop cavity spot resistant (orange) carrot cultivars

Marcou et al. 2021. Occurrence and anastomosis grouping of *Rhizoctonia* spp. inducing black scurf and greyish-white felt-like mycelium on carrot in Sweden. Journal of Fungi 7(5):396. doi: [10.3390/jof7050396](https://doi.org/10.3390/jof7050396)

Carrot USDA NIFA SCRI II Project

Applying advanced phenotypic and genomic tools to improve flavor, nutrition, and production traits in carrot (2022-2026)

Phil Simon et al.

- **OBJECTIVE 1: Develop cost-effective genomic tools to advance breeding populations and integrate loci for economically significant traits**
- **OBJECTIVE 2: Establish genomic-assisted breeding strategies for important traits.**
- **OBJECTIVE 3 - Evaluate bioavailability of nutrients in breeding stocks**
- **OBJECTIVE 4 - Estimate economic costs and benefits value to buyers and carrot industry of improved traits, and assess societal value of these improvements**

- **WA Role: Objective 2.**
- **Tim Waters:** Select PI lines planted in grower cooperator fields each spring. Plant stand, height, width, and vigor measured 6 weeks after planting. At harvest, roots dug manually, and assessed for top weight, root weight, shape, and other quality assessments. Roots of selected PIs with suitable commercial attributes shipped to Simon in WI for vernalization, additional testing, and crossing with inbred lines to incorporate resistance into lines with acceptable commercial traits.
- **Lindsey du Toit:** WSU Carrot Cavity Spot Nursery to screen breeding lines for resistance, and incorporate resistance into commercially suitable genetic backgrounds.