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Verticillium wilt of Potato:
Can we manage the disease without soil fumigants?

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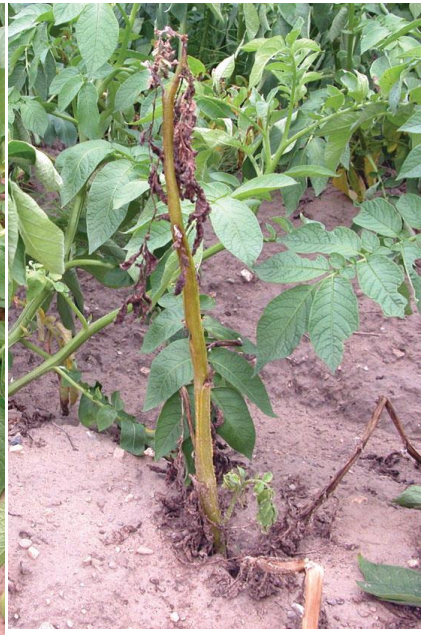
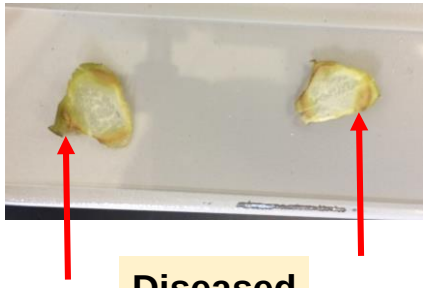
Verticillium wilt of potato: symptoms





Traditional management of Verticillium wilt of potato

Soil disinfestation: fumigation, solarization, biofumigation.

3-5 years crop rotations with non-susceptible hosts

- Moderate host resistance
- Cultural practices to improve plant and soil health

Integrated Management of Verticillium wilt:

Know the system well to make practices more effective

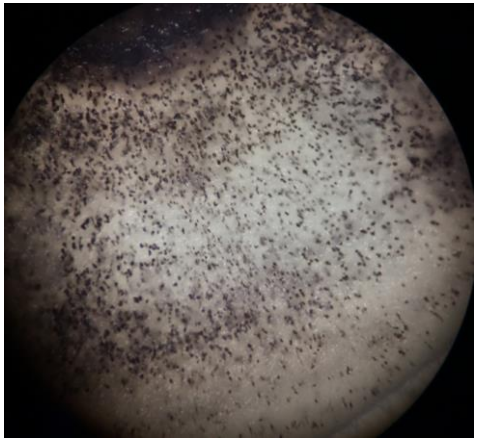
Verticillium wilt of potato: the pathogens

***Verticillium dahliae* (fungus)**

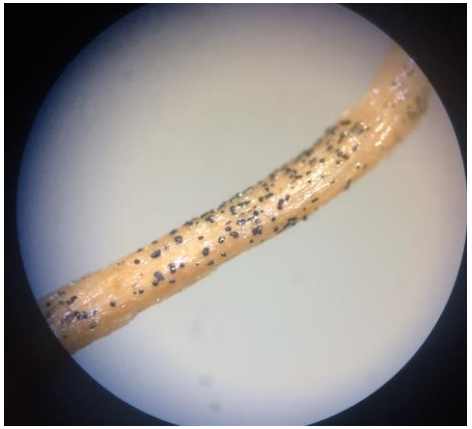
- Global distribution
- 300 plant species are susceptible, mainly dicotyledonous
- Survival: microsclerotia (> 5 years) or infecting plant material
- Disseminated with soil, water, plant material, equipment, etc.

***Verticillium albo-atrum* (fungus)**

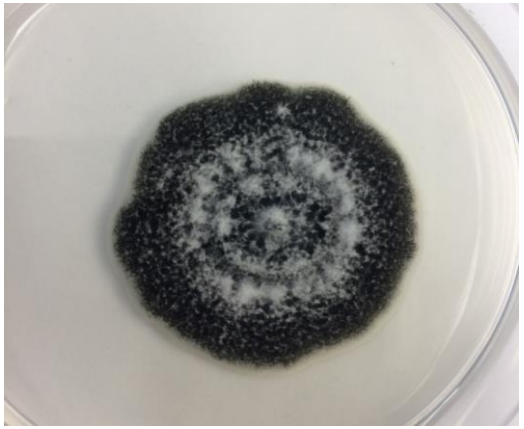
- Cooler climates: Canada, Germany, UK, northern Europe and northern USA



V. dahliae microsclerotia on nutritional media



Potato root colonized by *V. dahliae* microsclerotia



V. dahliae culture on nutritional media

EPPO database, 2017; Inderbitzin et al., 2011; APSnet.

Verticillium wilt of potato: the pathogens

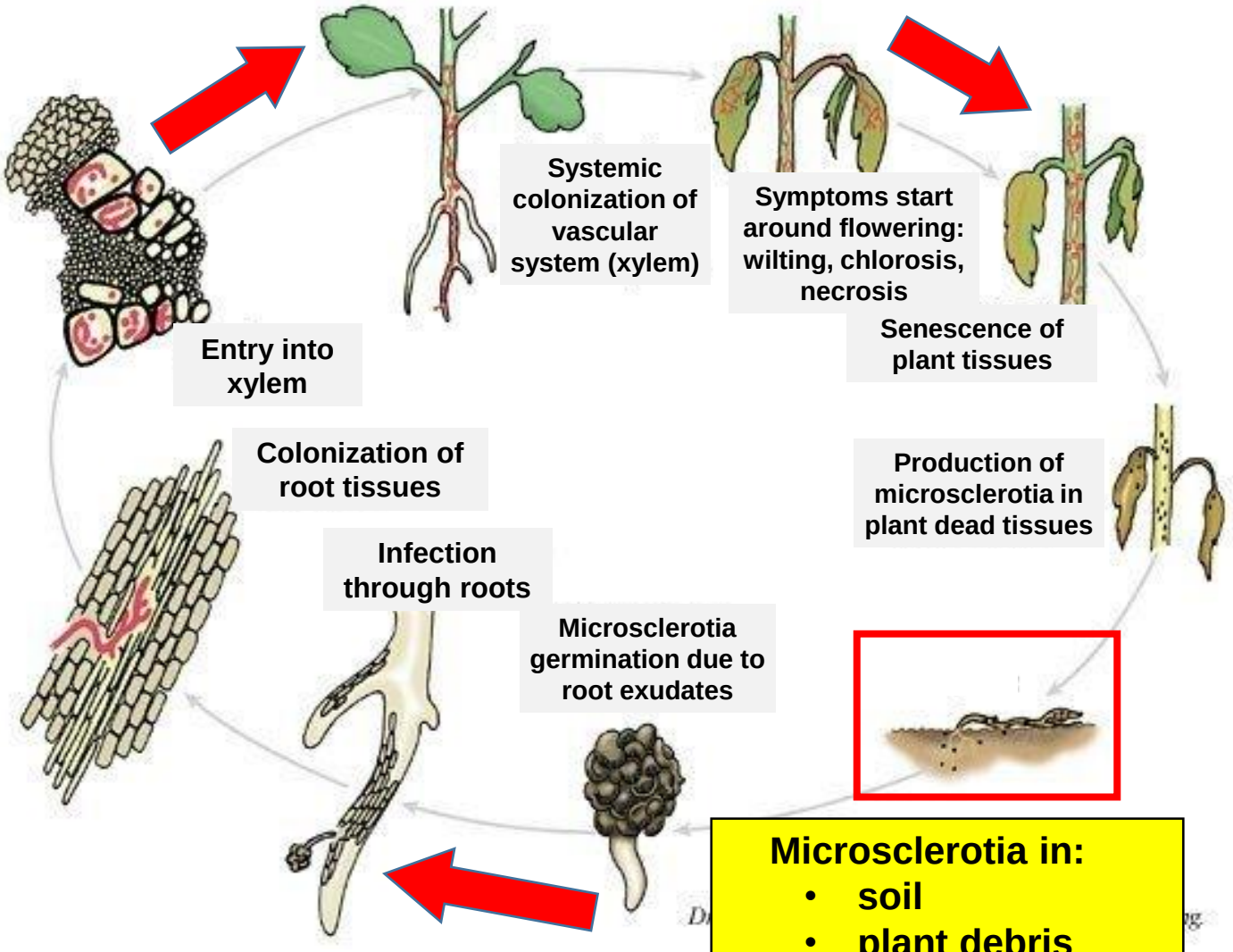
Potato Early Dying (PED) , a disease complex:

- *Verticillium* spp. (fungus) → Verticillium wilt
- *Colletotrichum coccodes* (fungus) → Black dot
- *Pratylenchus penetrans* (nematode) → Root lesion nematode

Wilting symptoms, difficult to distinguish from Verticillium wilt

EPPO database, 2017; APSnet.

Verticillium wilt of potato: disease cycle



Agrios; APSnet 2015

Management of Verticillium wilt of potato

Diversity of *Verticillium dahliae*, the main pathogen in potato systems:

Genotype	Geographical distribution	Severity of disease symptoms		Asymptomatic hosts
		Low or Medium	**High**	
1A	Mediterranean basin, South and Southeastern US (Texas, Alabama, California)	-	Cotton, olive, okra, artichoke	-
2A	US, Canada, Europe, Asia	Some Vegetable (except for resistant tomato and lettuce cultivars), herbaceous crops	Susceptible cultivars of tomato, lettuce	-
2B_334	Spain	Olive, cotton	artichoke	-
2B_824	US, Canada, Europe, Asia	Most vegetables, herbaceous crops, woody crops, ornamentals, etc.	-	Weeds
4A	**US, Canada**	-	**potato cultivars**	-
4B	US, Canada, Europe, Asia	Most vegetables, herbaceous crops, woody crops, ornamentals, etc.	-	Weeds, cereal crops (oats, wheat, corn, sorghum), mustard crops, etc.
6	California (US)	-	Pepper cultivars	-

Management of Verticillium wilt of potato

Diversity of *Verticillium dahliae*, the main pathogen in potato systems:

Pathogenicity test: symptoms on potato ‘Snowden’ at 2 months after inoculation

Verticillium dahliae **4B** genotype

V. dahliae **4A** genotype

Non-inoculated

Bautista-Jalon et al. 2018 (unpublished)

Management of Verticillium wilt of potato

Host resistance: selecting less susceptible potato cultivars

- No complete resistant cultivars available
  - Moderately-resistant/less susceptible cultivars:
    - cv. Ranger Russet
    - cv. Genesee
    - cv. Reba
    - cv. Atlantic
  - Avoid highly susceptible cultivars:
    - cv. Russet Norkotah
    - cv. Superior
    - cv. Snowden

But, resistance to what genotypes of *Verticillium dahliae*?

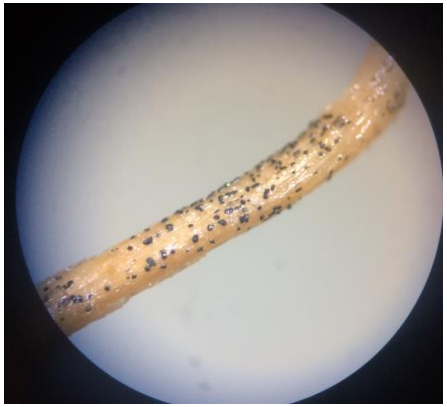
Mishanec et al. Potato Cultural Guide. Cornell University; APSnet 2018

Management of Verticillium wilt of potato

Crop rotations

Goal.- to separate disease cycles (production of microsclerotia) as much as possible in time to avoid soil inoculum (microsclerotia) build-up

- 4 - 5 years rotation with **non-hosts** (even longer if possible)
- > 5 years out of potatoes when severe epidemics
- > 200 plant species are susceptible to the disease
- Weeds and rotational crops can be infected by *Verticillium dahliae* without apparent symptoms: **Reservoirs of *V. dahliae***
  - Oat
  - Brown mustard
  - White mustard
  - Wheat
  - Austrian winter pea
  - Barley
  - Buckwheat
  - *Solanum* spp. weeds
  - Common weeds in Northeast: *Chenopodium* spp., *Amaranthus* spp., dandelion, etc.



Potato root colonized by *V. dahliae* microsclerotia

Bautista-Jalon et al. 2018 (unpublished); Wheeler and Johnson, 2016. Phytopathology 106:602-613.

Management of Verticillium wilt of potato

Crop rotations

Weeds and rotational crops from Pennsylvania and Israel potato fields were infected by ***Verticillium dahliae* lineage 4B** without apparent symptoms:

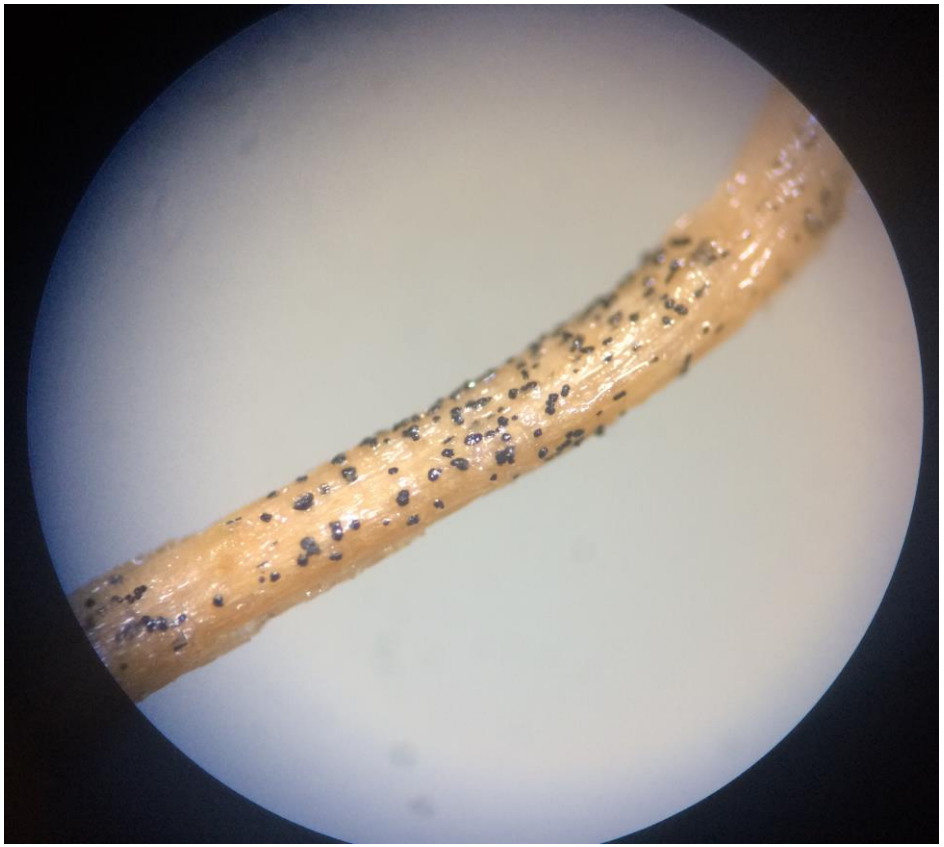
Host symptomatology	Host plant family	Host names	*V. dahliae* genotype
Asymptomatic	Amaranthaceae	*Amaranthus* spp. (pigweed species)	4B
	Asteraceae	*Calendula arvensis*, *Conyza bonariensis* (Asthmaweed)	4B
	Boraginaceae	*Heliotropium hirsutissimum*	4B
	Brassicaceae	*Diplotaxis* spp., *Sinapsis* spp., *Erucaria*, *Rapistrum* spp. (white rocket, wild mustards)	4B
	Convolvulaceae	*Convolvulus stachydifolius*	4B
	Fabaceae	**peanut**	4B
	Malvaceae	cheeseweed	4B
	Poaceae	**sorghum/millet**	4B
	Solanaceae	black nightshade, silverleaf nightshade	4B
	Poaceae	**oats**	4B
Symptomatic	Solanaceae	potato, pepper, eggplant, tomato	2A, 2B^{824}, 4A, 4B

Bautista-Jalon et al. 2018 (unpublished)

Management of Verticillium wilt of potato

Crop debris and weeds as source of *V. dahliae* inoculum

Potato stem colonized by *V. dahliae* microsclerotia



Potato root colonized by *V. dahliae* microsclerotia

Management of Verticillium wilt of potato

Potato Seed tubers: potential source of *V. dahliae* inoculum

- Certified potato seed tubers for seed-borne pathogens such as *Verticillium* spp., *Colletotrichum* spp., bacterial and virus pathogens.
- US: 30% of commercial seed lots (1995-1996) infected with *Verticillium dahliae*:
  - 4A -- 68% of the infections
  - 4B -- 33% of the infections
- Israel: Imported potato seed lots from Netherlands (1995-1998) contaminated by *Verticillium dahliae*, *Colletotrichum coccodes*, etc.
- Mini-tubers from tissue culture – or micropropagation: multiplying disease-free plants in controlled conditions (laboratory environments) that can then be used to produce healthy seed tubers

Omer et al., 2000. Am. J. Potato Res. 77:325-331; Tsror et al., 1999. Phytoparasitica 27:215-226; http://www.potato-seed.com/

Management of Verticillium wilt of potato

Cultural practices on soil and crop health

- **Organic content**, high soil fertility: organic amendments
- **Tillage:** exposed microsclerotia to sun (UV radiation), heat.
- **Remove** of **symptomatic potatoes**, **crop debris and weeds** from field (as much as possible)
- Proper **fertilization** of potato crops: keep adequate nitrogen levels. Healthy plants slow down disease progress.
- Proper **irrigation**: avoid water stress (lack or excess of water) in potato crops

Inderbitzin et al., 2018. Phytopathology 108:31-43; APSnet 2018; Rowe, R.C. and M.L. Powelson. 2002. Plant Dis. 86:1184-1193.

Management of Verticillium wilt of potato

Cultural practices on soil and crop health

- **Soil analysis** to estimate ***Verticillium dahliae*** **inoculum levels** in the field: certificated laboratories, extension services → **what about genotypes?**
    - Developing tools to detect and quantify 4A and 4B genotypes in soil, plant material, etc. Work in progress.

- **Soil microbiome**.- enhancing beneficial soil microorganisms <-> soil fertility
    - Chitin-based soil amendments such as crab, lobster, shrimp byproducts from seafood industry
    - Organic amendments: green manures, compost.

Inderbitzin et al., 2018. Phytopathology 108:31-43; APSnet 2018; Rowe, R.C. and M.L. Powelson. 2002. Plant Dis. 86:1184-1193.

Management of Verticillium wilt of potato

Soil treatments: acting on soil microsclerotia

- **Solarization**.- irrigate soil to saturation and tarp (white plastic) for weeks. Only effective if soil temperature of >100 °F at 5 cm depth for 4–6 weeks.
- **Biofumigation**.- cruciferous/brassica crop residues amendments and green manures: broccoli, cauliflower, arugula, oilseed rape, Sudan grass, etc.
    - Remember mustard crops can be asymptomatic hosts of the pathogen!
- **Fumigation**.- synthetic chemicals
- **Steam treatments**.- soil temperature 158–212 °F (70-100 °C) for at least 20 min
- **Anaerobic Soil Disinfestation (ASD)**.- soil disinfestation technique that uses anaerobic conditions and microbial activity to manage weeds, soil-borne pests and diseases.
    - **Add carbon source + incorporate into soil**
    - **Irrigate soil to saturation**
    - **Cover soil with plastic mulch: soil temperature > 85 °F (30 °C) and anaerobic conditions for at least 3 weeks**

More effective with warmer soil temperatures and longer tarping periods

APSnet 2018; Rowe, R.C. and M.L. Powelson. 2002. Plant Dis. 86:1184-1193; Shennan et al., 2018. Plant Pathology 67: 51-66.

Anaerobic Soil Disinfestation for Management of Soilborne Diseases in Midwestern Vegetable Production

Soilborne pathogens sensitive to ASD:

- **Fungi**: *Fusarium* spp., *Verticillium dahliae*, *Rhizoctonia solani*, *Sclerotium rolfsii*, *Pyrenochaeta lycopersici*, *Colletotrichum coccodes*
- **Oomycetes**: *Phytophthora* and *Pythium* spp.
- **Nematodes**: Root knot nematodes (*Meloidogyne* spp.) and lesion nematodes (*Pratylenchus penetrans*)
- **Bacteria**: *Agrobacterium tumefaciens*, *Ralstonia solanacearum* (brown rot)

Testen and Miller, 2018. Ohioline.; Testen and Miller, 2018. Phytobiomes 2: 138-150

Management of Verticillium wilt of potato

Anaerobic soil disinfestation (ASD) for Northeast potato systems

Important factors that need to be adapted or designed for potato systems:

- **Timing**: When to implement ASD? Best conditions are during the growing season

  rule of thumb: minimum 3 weeks at > 85 °F
- **Amendments**: which carbon sources are available in the area and suitable for this?
- **Irrigation** to saturate soil: rain-fed? irrigation system?
- **Coverage** with **plastic mulch**: coverage strategies appropriate for potato field

Summary and conclusions

- Diversity of *Verticillium dahliae* matters: **4A is the most aggressive genotype to potato** and is present in North America potato systems.

- **No cultivars with complete resistance** -> breeding for Verticillium wilt resistance considering *V. dahliae* genotypes is necessary.

- **Crop rotations** are **useful but often not very effective**: asymptomatic infections of *V. dahliae* 4B genotype in weeds and rotational crops. More research is needed to understand effects.

- Potato **seed** tuber **certification for seed-borne pathogens** and more tissue-culture propagation are necessary

- Cultural practices are important to maintain **soil and crop health**. Water and nutrient stress affect symptoms development.

- **Soil treatments to eradicate microsclerotia** are necessary once the pathogen is established and reaches certain inoculum level.

- **Anaerobic Soil Disinfestation** seems an effective tool to eradicate *V. dahliae* from soil, and alternative to chemical fumigation. It needs to be adapted to potato systems though.

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Resources for more information:

- Anaerobic Soil Disinfestation for Management of Soilborne Diseases in Midwestern Vegetable Production. Testen A.L. and Miller S.A. Ohio State University Extension.
- APSnet. American Phytopathological Society.
- Penn State Plant Pathology Extension
- Penn State University – Plant Disease Clinic