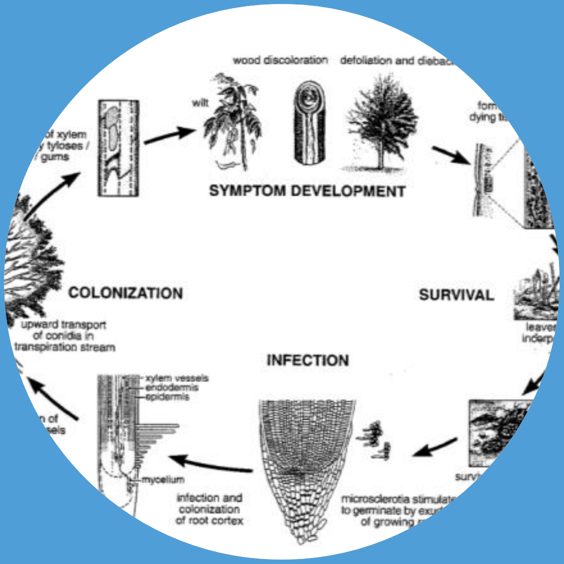
Spatial and temporal aspects of Verticillium wilt in trees and resistance against V. dahliae

Jelle Hiemstra

Göttingen, May 6th 2013



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Symptoms in woody hosts

- 3 main types of effects:
  - Leaf symptoms: wilt, discolouration, defoliation, drying/necrosis
  - Vascular symptoms: discolouration of xylem, plugging of vessels
  - Decline: stunting, dieback, death
  - Occasionally: elongated dead areas of bark on stem/branches; flower and fruit mummification




Tree hosts of VW

Forest/street/shade trees		**Fruiting species**	
Host	Non-host	Host	Non-host
Acer	*Alnus*	*Coffea*	*Malus*
Aesculus	*Betula*	*Cydonia*	*Pyrus*
Ailanthus	*Fagus*	*Olea*	
Castanea	*Populus*	*Persea*	
Catalpa	*Quercus*	*Pistacia*	
Cercis	*Salix*	*Prunus*	
Fraxinus		*Rubus*	
Liriodendron		*Theobroma*	
Magnolia			
Robinia			
Tilia			
Ulmus			

Cause of VW in trees: ***V. dahliae*** (“microsclerotial form of Vaa”)

Tree hosts and damage

- Different categories
  - Fruit production: olive, stone fruits, pistachio
  - Tree nursery: shade trees & ornamentals
  - Urban and Landscape trees
  - Forest trees ???

Verticillium wilt in forest stands ?

- NL; 1970's-1980's: VW of Fraxinus excelsior
  - Young forest plots in Flevopolders
  - Landscape / recreational plantings
  - Not in older forests

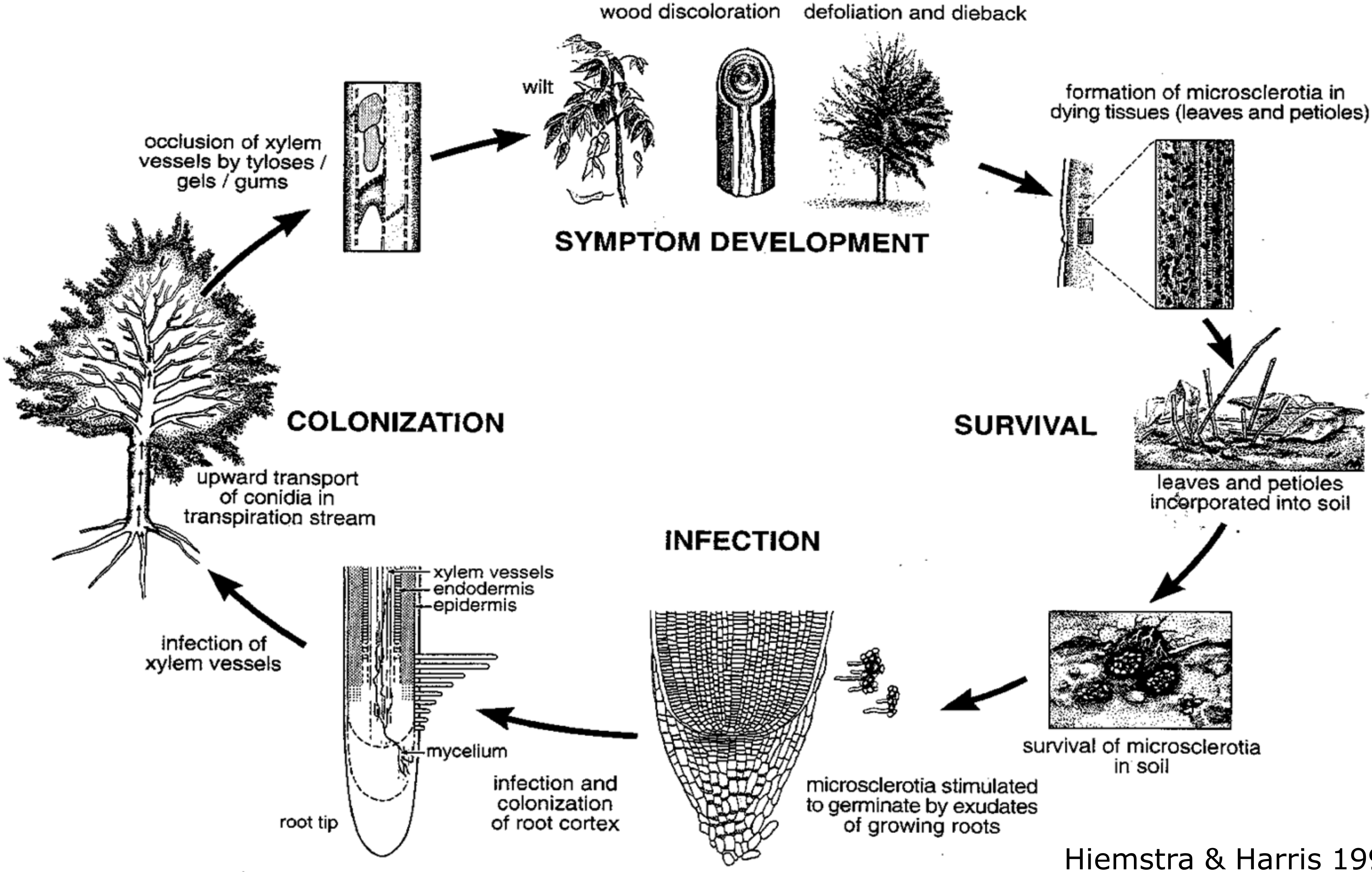
Verticillium wilt in forest stands ?

- Literature: very limited number of reports
  - *Ceanothus integerrimus* (Harrington & Cobb; 1984)
    - Coastal forest in California -- Vaa
  - *Liriodendron tulipifera* (Donahue & Morehart; 1978)
    - Urban and forest settings in Delaware -- Vd and Vaa
  - *Ailanthus altissima* (Schall and Davis; 2009)
    - Mixed hardwood forests in Pennsylvania – Vaa

→ *Verticillium nonalfalfae* !

- Mature (natural ?) forests VW very rare !!
  - Reason?

Disease cycle of *V. dahliae* in trees

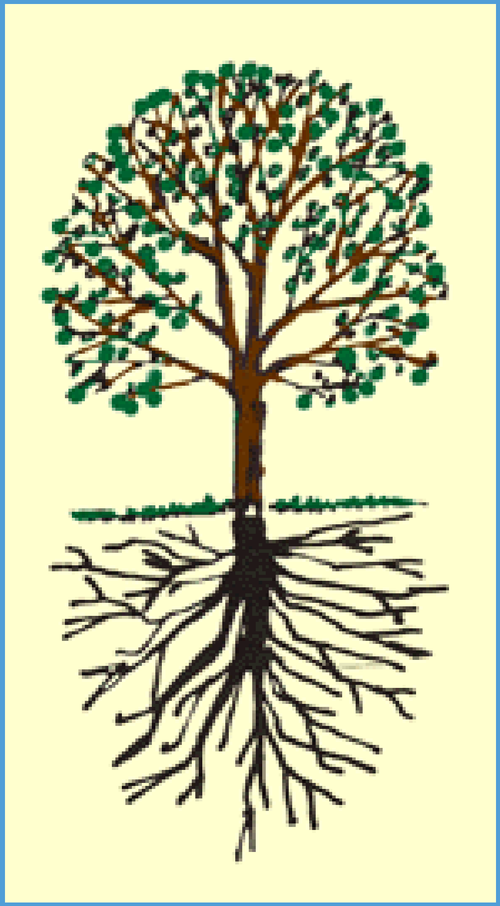


Hiemstra & Harris 1998

Special features of VW in trees

- Size of host
- Long-life of host
- Xylem anatomy

VW in Trees → Size effects



- Root system
    - covers large soil volume
    - each year major part fine roots renewed
    - roots not only in top layer
    - low IC → still contact many ms
- Damage threshold level often low
    - *Acer & Catalpa* (Goud, 2003):
      5% damage threshold = 1-2 CFU/g soil
    - *Pistachio* (Ashworth & Zimmerman, 1976)
      10-14% died at ID 1-2 ms/g soil
    - *Olive ?*

Special features of VW in trees

- Size of host

- **Long-life of host**
  - VW is mono-cyclic (year) BUT poly-cyclic (life-time)

    → repeated infections possible in life of tree
  - Secondary inoculum may affect same tree

Secondary inoculum: *Acer platanoides*

Hiemstra, 1997

>50% petioles infected (10-94%)

inoculation experiment → 10% VW in young *A.plat.* trees

Secondary inoculum: *Fraxinus excelsior*

Rijkers *et al.*, 1997



14% of soil incubated petioles contained Vd ms

Avg 1500 ms/cm (not equally spread)

Secondary inoculum & trees

- Petioles
  - **Acer** (Zimm, 1918; Townsend *et al.*, 1990; Hiemstra, 1997): **50%**
  - **Fraxinus** (Rijkers *et al*., 1992) ***14%***
  - **Liriodendron** (Morehart & Melchior, 1982) **+**
  - **Olea** (Tjamos&Botseas,1987: **68%**; Tjamos&Tsougriani,1990: ***10%***)

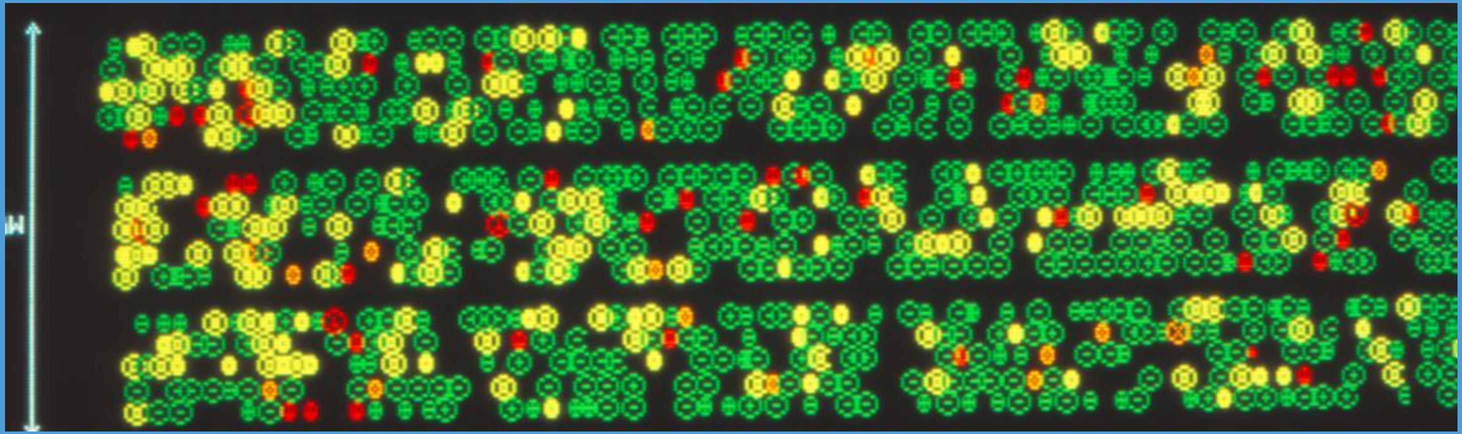
- Inflorescences
  - **Olea** (Trapero *et al.*, 2011):

    up to over **70 ppg** (peduncles) / **7 ppg** (flowers)

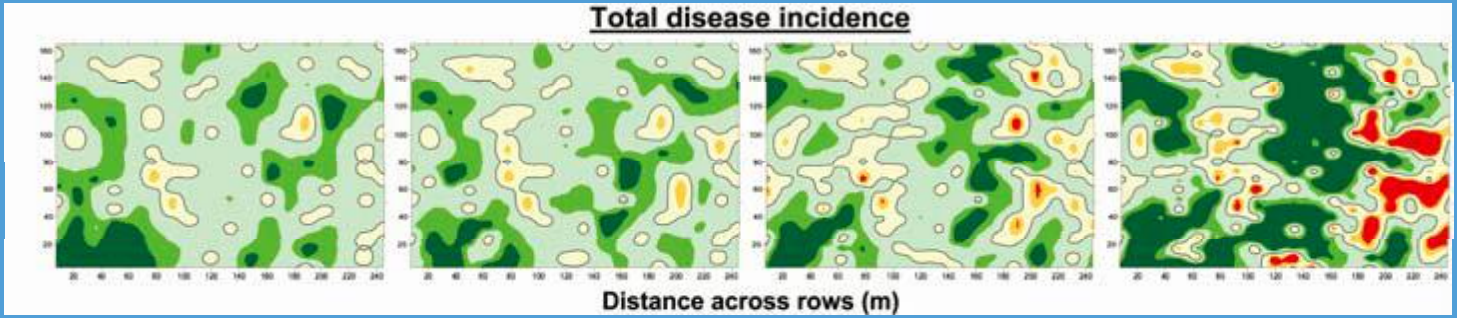
- **Sec. inoc. can substantially contribute to VW in trees**

Distribution pattern of VW

- Patches of higher density superimposed on a general distribution at lower density
  - VW of *Fraxinus excelsior* in forests in NL (Hiemstra, 1995)



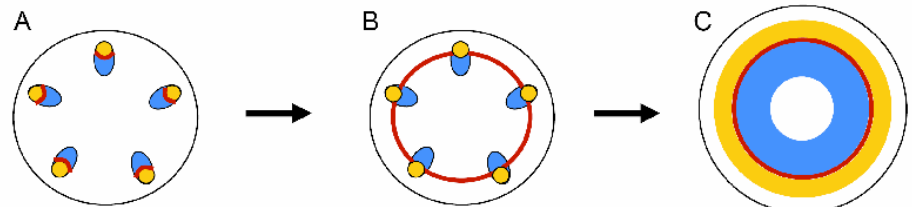
  - VW of *Olea europaea* in orchards in SP (Navas *et al*., 2011)



Special features of VW in trees

- Size of host
- Long-life of host & secondary inoculum
- **Xylem anatomy**
  - Anatomy affects colonization and symptom development
  - Annual production of new vascular tissue =
    built-in mechanism for recovery
  - Anatomy may contribute to resistance

Xylem anatomy of trees → Secondary growth



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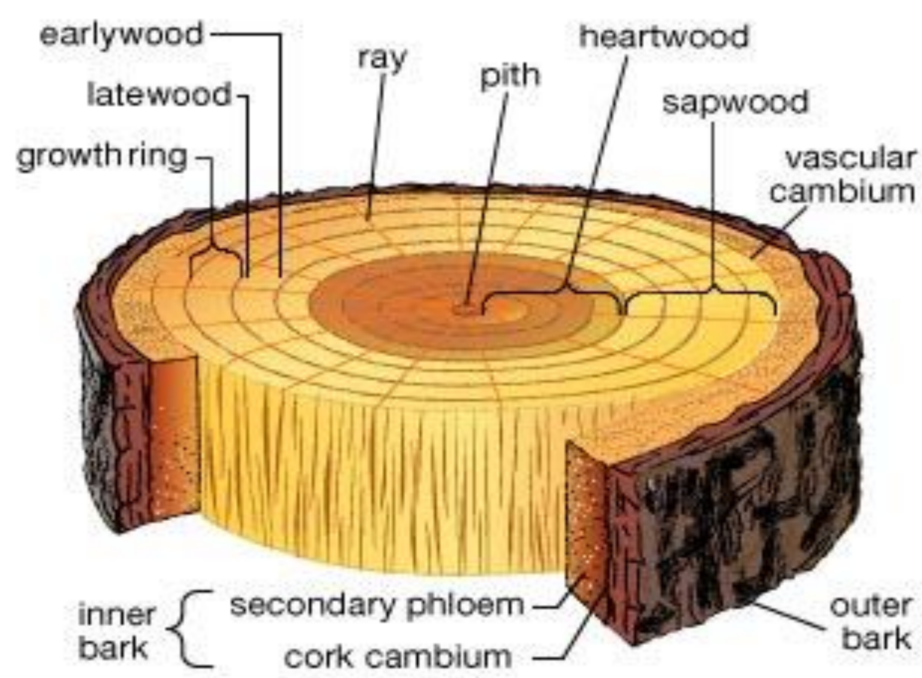

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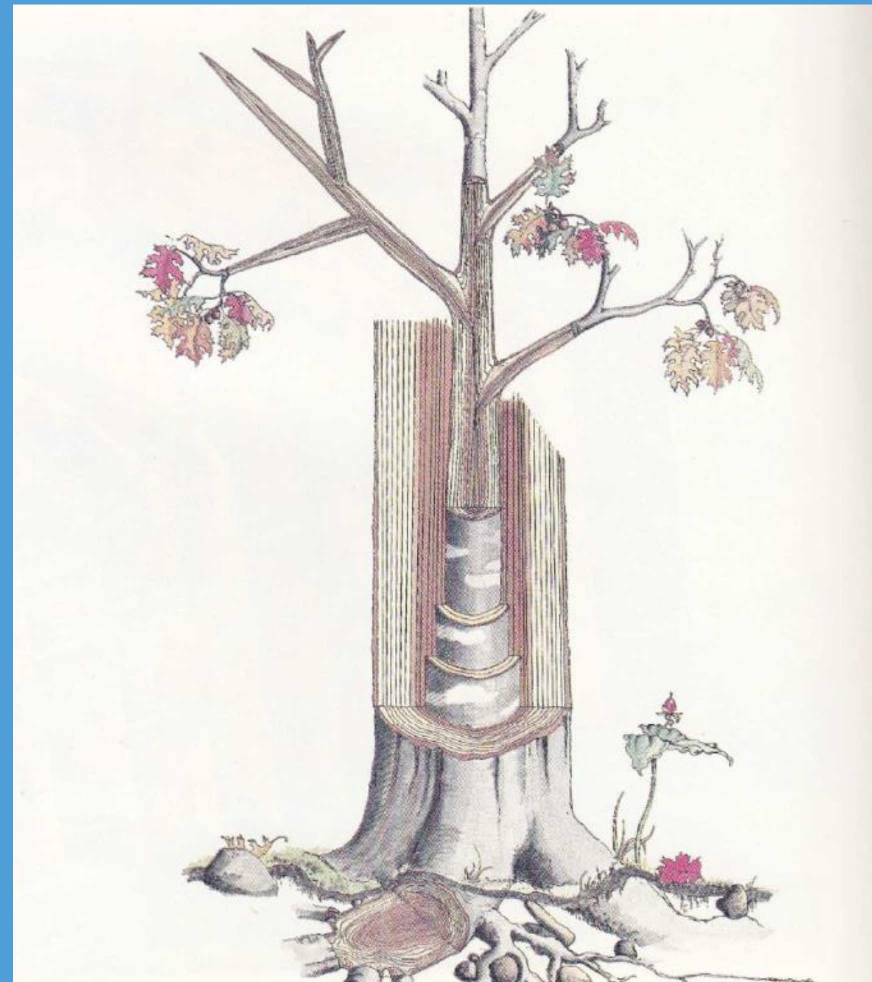

Figure 17

Shigo, 1979

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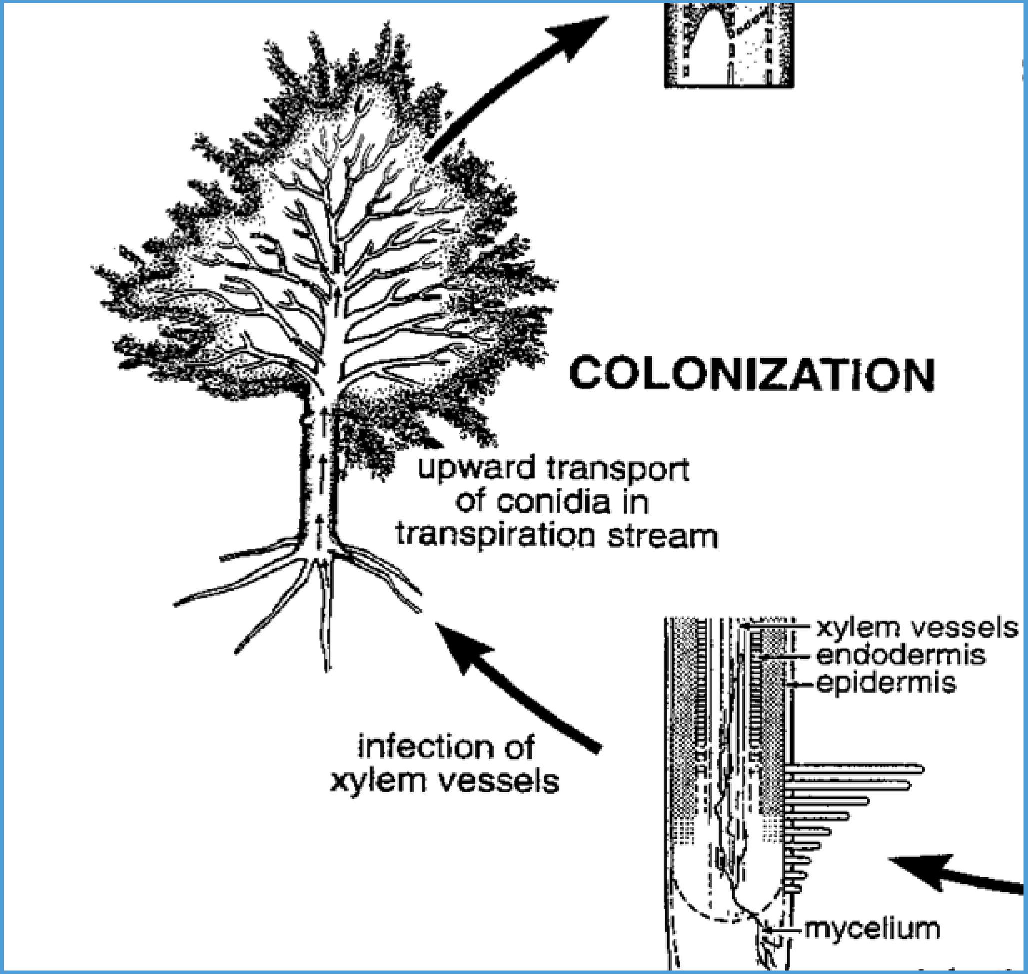
Colonization of tree body



- Penetration of root
- Colonization of cortex
- Penetration of endodermis
- Entry into xylem
- Behaviour changes:

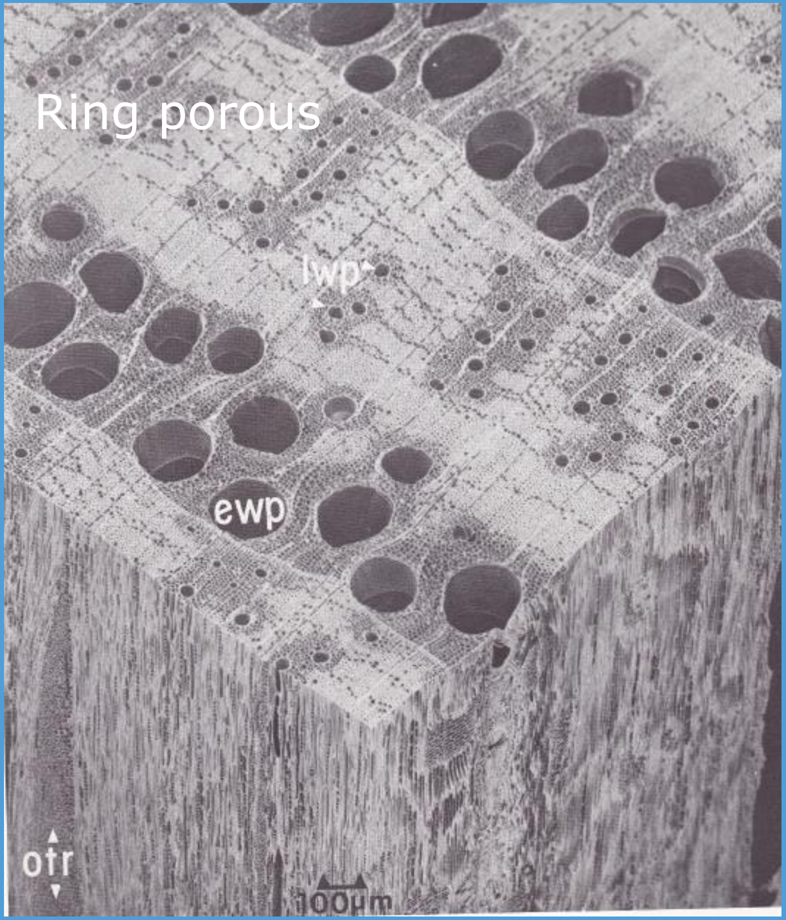
only in xylem vessels

conidia → fast upward transport

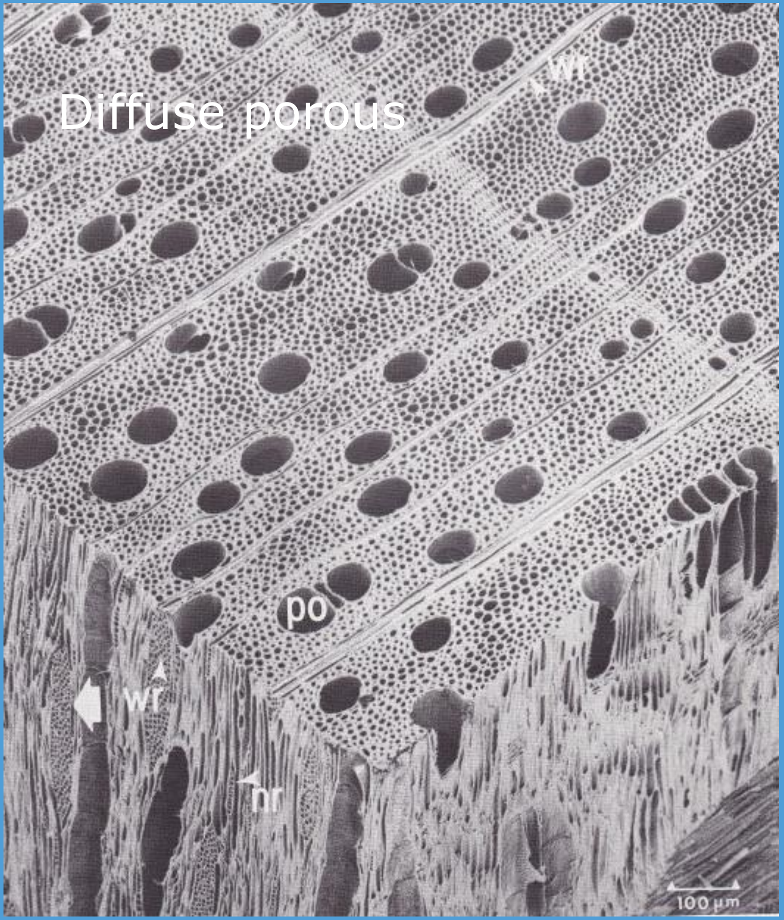
(see Prieto *et al.*, 2009)

Xylem anatomy of trees

Core *et al.*, 1976



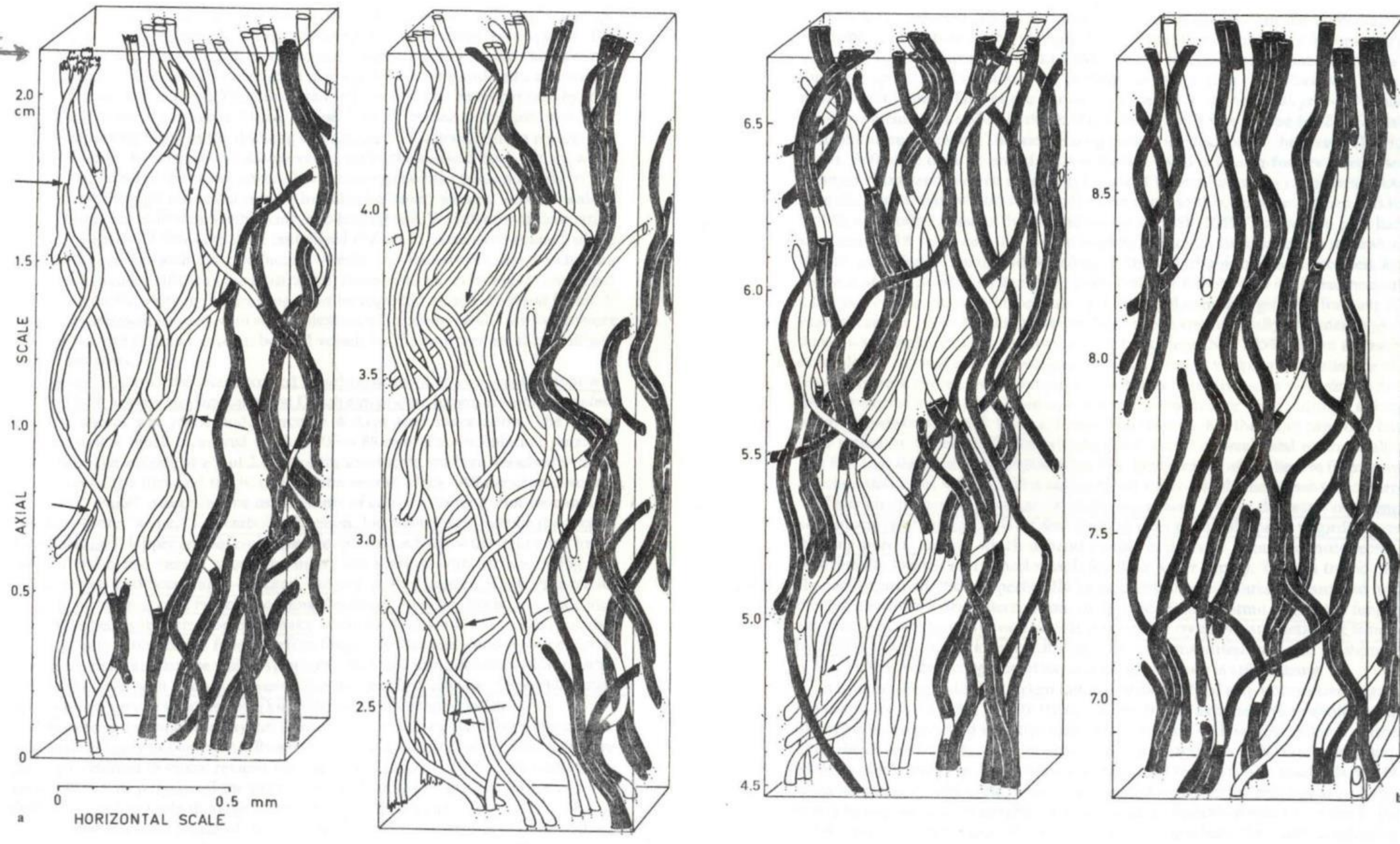
3 m; up to > 10 m
16-45 m/h



10 cm; up to 0.5 m
1-6 m/h

Xylem vessel network

Zimmermann, 1983



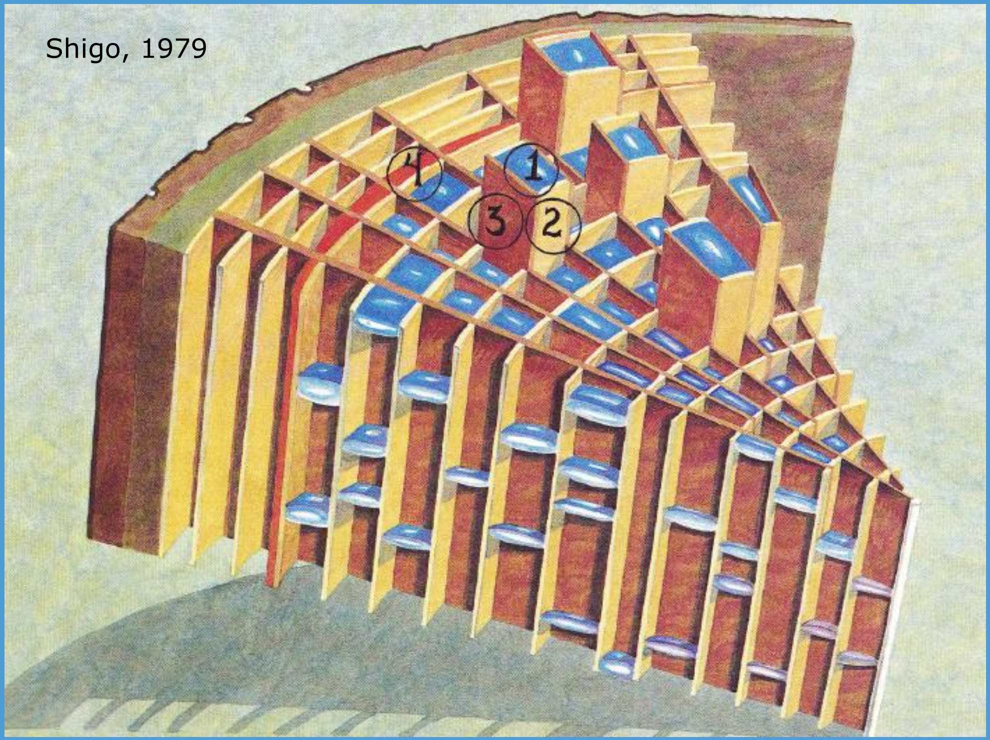
Vessel network & distribution of conidia

- Passive transport by sapstream
  - Upward & tangential distribution
  - Extent depends on species
  - Influenced by active reaction of host
- Examples
  - Ash: strongly interconnected vessels (Zimmermann, 1983)
  - Olive: ind. roots strong connection with ind. branches (Lavee, 1996)

Xylem build-up enables recovery of trees

A.L. Shigo: **CODIT-model**

- highly compartmented
- active response
- “multiple” plant
- new xylem every year



Tippett & Shigo, 1981:

Wall 1: vascular occlusions

Wall 2: margins of growth rings

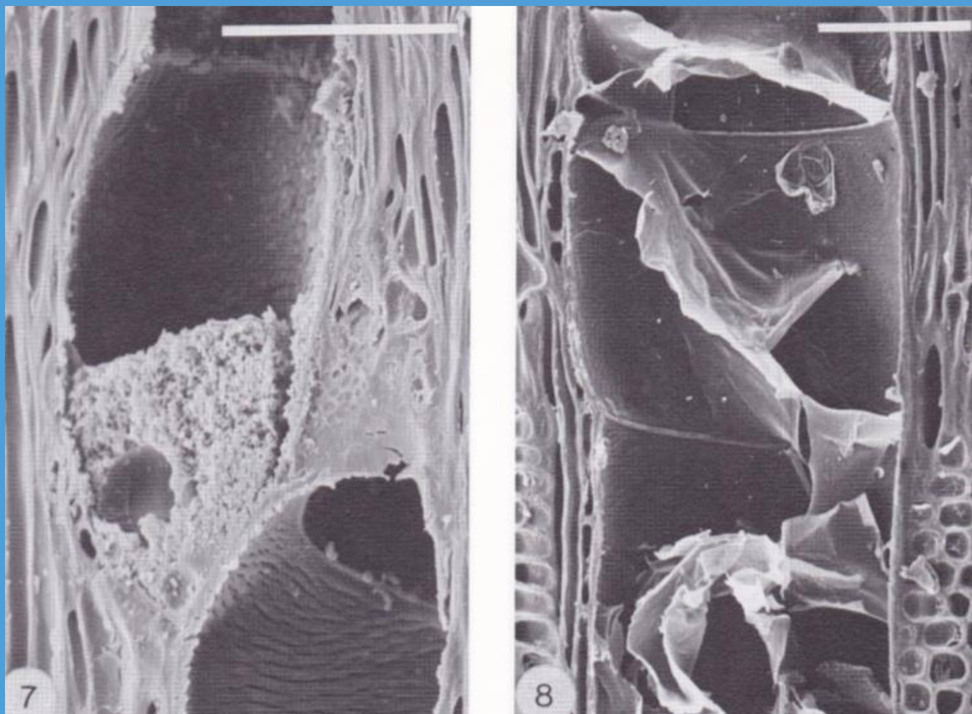
Wall 3: sheets of ray cells

Wall 4: formation of barrier zone

Recovery from VW in tree hosts

- Cherry — Van der Meer, 1925
- Peach — Ciccarese *et al.*, 1990
- Apricot — Taylor & Flentje, 1968; Vigouroux & Castelain, 1969; Harrison & Glare, 1970
- Almond — Cirulli *et al.*, 1998
- Cacao — Emechebe *et al.*, 1974
- Olive — Wilhelm & Taylor, 1965; Vigouroux, 1975
- Ash — Hiemstra, 1995
- Maple — Sinclair *et al.*, 1981

Active response of *Fraxinus excelsior*



Miller & Hiemstra, 1987

- Extensive vascular occlusion
- No barrier zone →
  marginal parenchyma band

Recovery can be very effective

Ash (*Fraxinus excelsior*)

		% recovery	% dieback/dead
Natural infection	Forest trees	40	40
	Landscape trees	56	13
Inoculated trees		100	0

Hiemstra, 1995

- Infection type matters

Recovery can be very effective

Olive (*Olea europaea*)

		ND	D
Inoculated trees		86 %	24 %
	R	100	
	MS	90	83
	S	81	36
	ES	56	9

López-Escudero & Blanco-López, 2005

- Resistance level of cv
- Virulence of pathogen (D/ND)

Recovery - summary

- Mechanism
  - Confinement of pathogen
  - Formation of new uninfected xylem
  - Dieback/death only when pathogen reaches cambium
  - Pathogen seems to “disappear” gradually

Anatomy provides structure and opportunity;

active response by host (and interaction with pathogen) is decisive

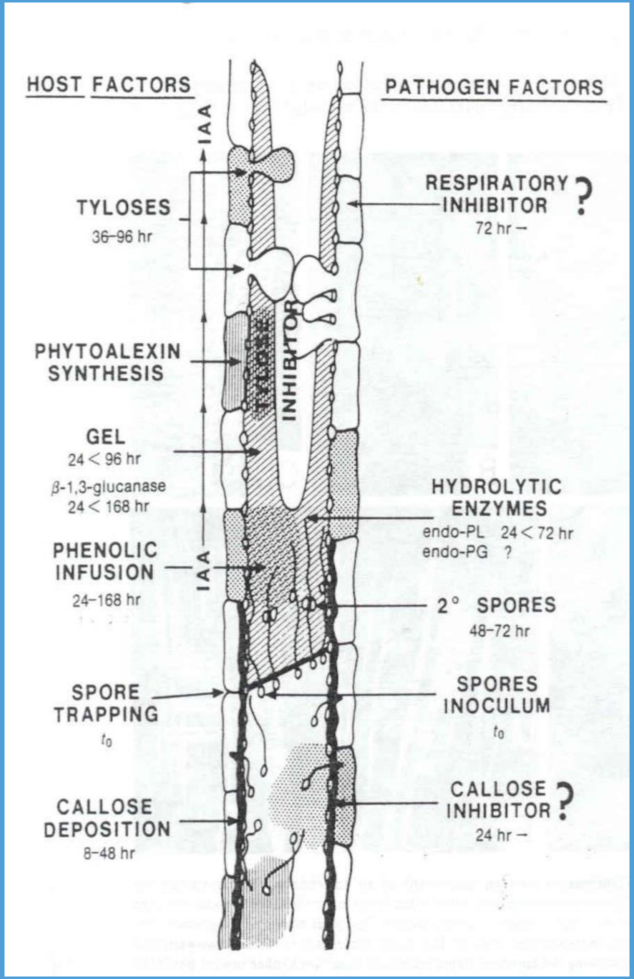
→ Link to Resistance

Resistance to VW

- 2 types (Fradin & Thomma, 2006)
  - Polygenic: alfalfa, cotton, potato, strawberry
  - Single dominant R-gene: cotton, sunflower, potato, tomato
- Tree hosts
  - Long history of screening & selection for R
    - Olive, maple, prunus, pistacia
  - No information on R-genes
  - Processes similar as described for recovery
    - Anatomical factors contribute
    - Active response of the host decisive

Response of host

- Many mechanisms available
  - To avoid vascular infection
  - To block vascular distribution
  - To eliminate the pathogen once established
- Probably "there is no magic key to understanding all Verticillium infections" (J. Robb, 2007)
- Concept of time/space frame still valid and very useful



Beckman, 1984

Implications for integrated control

- Trees live long → prevent building-up of sec. inoculum
  - Make sure planting material is not infected
  - Remove diseased trees from new plantations
- Trees have a built-in recovery system
  - Pruning diseased branches may stimulate recovery
- Individuals often vary in susceptibility
  - Rootstock with increased level of resistance may protect susceptible commercially important cultivars

Thank you for your attention