Vineyard Soil Pests and Management

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Outline

- Types of Nematodes and Their Damage
- Phylloxera and Their Damage
- Resistant Rootstocks
- Other Ways to Control Soil Pests

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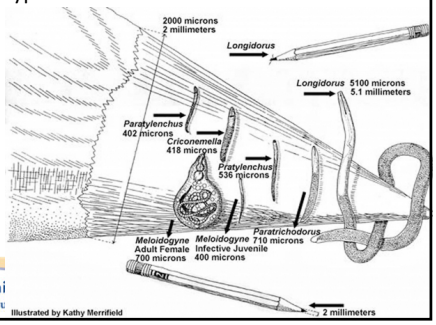
Types of Nematodes

- How big are nematodes
- Nematodes are generally broken into two categories
  - Ectoparasites that live outside root
  - Endoparasites that live inside root



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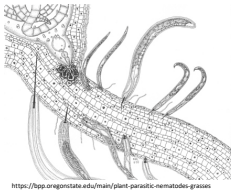
Types of Nematodes

- There are many different types of Nematodes that affect grapes
  - Ectoparasite (live outside root)
    - Dagger nematodes
      - *Xiphinema index*
      - *Xiphinema americanum*
    - Ring nematodes
      - *Mesocriconema xenoplax*
    - Stubby root nematode
      - *Paratrichodorus spp.*
    - Pin Nematode
      - *Paratylenchus hamatus*



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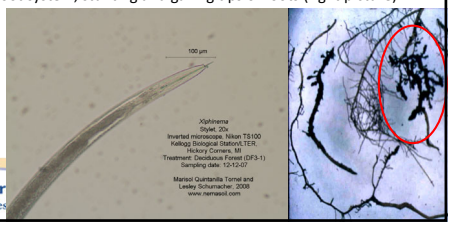
Types of Nematodes

- Dagger nematode, *Xiphinema index*
- Named for the dagger-like feeding Stylet (left picture)
- Cause direct damage to root system, stunting and galling tips of roots (right picture)
- Leads to vigor losses



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Types of Nematodes

- Dagger nematode, *Xiphinema index*
- Also vectors Grapevine Fanleaf Virus
- Massive yield losses (80%)

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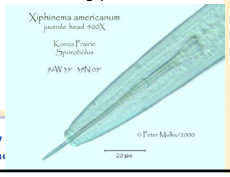
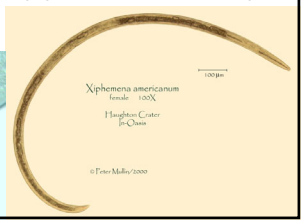
Types of Nematodes

- Dagger nematode, *X. americanum*
- Most common species of dagger nematode
- Feeds near the root tip, but does not cause the large galls seen with *X. index* feeding
- Large populations will lead to vigor losses
- Does vector the tomato ringspot virus





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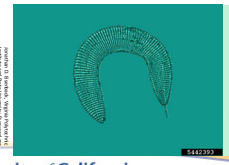
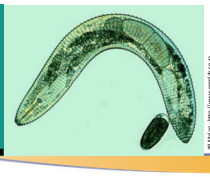
Types of Nematodes

- Ring Nematode - *Mesocriconema* (*Criconemella*) *xenoplax*
  - Feeds from outside the root with a long stylet
  - Causes a reduction in the number of small feeder roots
  - Leads to overall reduction in plant growth, especially in young plants





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Types of Nematodes

- Stubby root nematode
  - *Paratrichodorus spp.*
  - Feeding lead to stubby root growth
  - More common in sandy soils
  - Reduce vigor and yield in heavily infested vines

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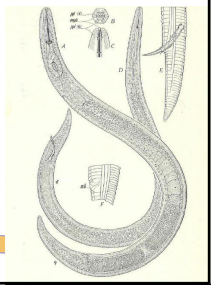
Types of Nematodes

- Pin Nematode
  - *Paratylenchus hamatus*
  - Highly abundant, but not normally associated with damage
  - Can damage young vine with large population
  - Feeding in large numbers produce shallow localized lesions



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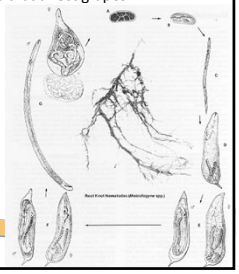
Types of Nematodes

- There are many different types of Nematodes that affect grapes
  - Endoparasite (live inside root)
    - Root knot nematodes
      - *Meloidogyne incognita*
      - Other *Meloidogyne spp.*
    - Lesion nematode
      - *Pratylenchus vulnus*
    - Citrus nematodes
      - *Tylenchulus semipenetrans*



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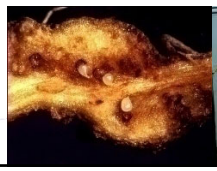
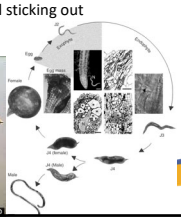
Types of Nematodes

- Root knot nematodes: Meloidogyne incognita (M. javanica, M. arenaria, and M. hapla)
- Root knot nematodes live most of their lives as endophytes – live inside of their host
- Females live inside the roots creating a gall with only their tail sticking out





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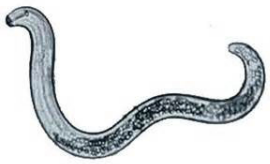
Types of Nematodes

- Lesion Nematode - *Pratylenchus vulnus*
  - Penetrate root and migrates through cell in root cortex
  - Leaves behind a lesion on the root surface
  - This lesion can be exploited by fungi to invade root tissue
  - Young vines planted in infested soil see severely restricted root growth



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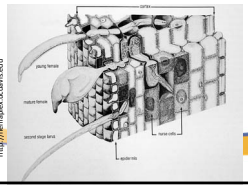
Types of Nematodes

- Citrus Nematode - *Tylenchulus semipenetrans*
  - Live both inside (feeding) and outside (egg laying) of the root
  - Egg masses covered in sticky gelatin, which sticks to dirt causing infested roots to look dirty
  - Feeding causes death of feeder roots, lowering plant growth/vigor



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Outline

- Types of Nematodes and Their Damage
- **Phylloxera and Their Damage**
- Resistant Rootstocks
- Other Ways to Control Soil Pests

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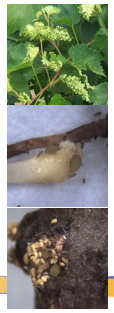
Phylloxera

- 3 Types of Phylloxera Feeding
  - Foliar Feeding
    - Primarily effects American *Vitis* species
    - Leads to shorter and thinner shoots
  - Root Tip Feeding (Nodosity)
    - Effects most *Vitis* species
    - Little to no effect on established vine
  - Primary Root Feeding (Tuberosity)
    - Primarily effects *V. vinifera*
    - Leads to vine death



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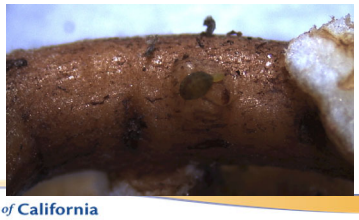
Phylloxera

- Identifying Tuberocities
  - Tuberocities start as an unusual lump/growth on lignified root tissue



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Phylloxera

- Identifying Tuberocities
  - Tuberocities start as an unusual lump/growth on lignified root tissue
  - This often matures into a "blown out volcano" look

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Phylloxera

- Identifying Tuberocities
  - Tuberocities start as an unusual lump/growth on lignified root tissue
  - This often matures into a "blown out volcano" look
  - Depending on the roughness of the root itself this formation may be hard to identify

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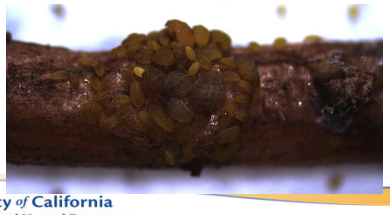
Phylloxera

- Identifying Tuberocities
  - Once formed other crawlers will start feeding



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Phylloxera

- Identifying Tuberocities
  - Once formed other crawlers will start feeding
    - And mature into adults themselves

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Phylloxera

- Identifying Tuberocities
  - In the end things can really buildup

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Phylloxera

- Identifying Nodosities
  - Nodosities start as a swollen spot normally near the tip of the root
    - (when the crawler started feeding)

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Phylloxera

- Identifying Nodosities
  - As the root continues to grow past the feeding site it often leads to a hook or bend

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Phylloxera

- Identifying Nodosities
  - Hooking doesn't always happen

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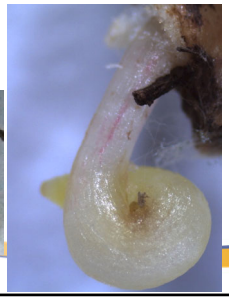
Phylloxera

- Identifying Nodosities
  - And sometimes the hook never stops
  - Or you get a second bend



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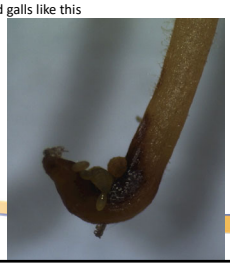
Phylloxera

- Identifying Nodosities
  - Oddities aside you will normally find galls like this



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Phylloxera

- Identifying Nodosities
  - Or these

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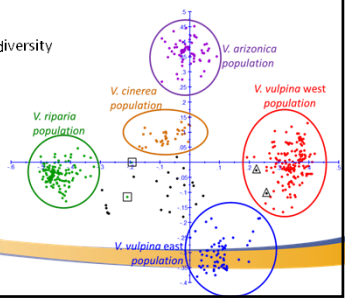
Phylloxera

- Phylloxera are a single species, but
- Phylloxera also show a large amount of diversity
- This also leads to a complex resistance..
- But that's for the next section



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Outline

- Types of Nematodes and Their Damage
- Phylloxera and Their Damage
- **Resistant Rootstocks**
- Other Ways to Control Soil Pests

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Phylloxera Resistant Rootstocks

- Diversity in a pest leads to diversity in resistance
  - Phylloxera Isolates
    - 1 Isolate from Chardonnay (Vin-R1)
    - 1 Isolate from AxR#1 (AxR-R1)
    - 2 Isolates from 101-14 roots (101-R1 & 101-R2)
    - 2 Isolates from foliar galls (101-L1, StG-L1)
  - Isolates Tested Against Roots of 9 Hosts
    - Colombard (S)
    - AxR#1 (S, BioA vs BioB)
    - 2 *V. riparia* (T&R)
    - 2 *V. rupestris* (T&R)
    - 2 *V. berlandieri* (T&R)
    - *V. rotundifolia* (R)

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Phylloxera Resistant Rootstocks

- 30 Day Feeding Trials
- Excised Root Assay
  - Compact
  - Contained
  - Cost effective
- Categorized Results
  - Control: Vin-R1 on Colombard

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Phylloxera Resistant Rootstocks

Root Source \ Phylloxera Type	101-L1 (Fol)	StG-L1 (Fol)	101-R1	101-R2	AxR-1 (Bio B)	Vin-R1 (Bio A)
Colombard	Slow/Low	Res.*	Slow/Low	Slow/High	Fast/High	Fast/High
AxR#1	Slow/High	Fast/High	Fast/High	Fast/High	Fast/High	Res.*
V. berlandieri 9043	Slow/High	Slow/Low	Slow/High	Slow/High	Fast/High	Res.
V. riparia 1411	Fast/High	Fast/High	Slow/High	Slow/High	Fast/High	Fast/High
St. George	Fast/High	Fast/High	Slow/High	Slow/High	Slow/High	Slow/High
V. berlandieri 9031	Slow/Low	Slow/Low	Res.	Res.	Res.	Res.
V. riparia 1437	Res.	Res.	Slow/High	Fast/High	Res.	Res.
V. rupestris Ganzin	Res.	Res.	Slow/Low	Slow/High	Slow/Low	Res.
V. rotundifolia Trayshed	Res.	Res.	Res.	Res.	Res.	Res.
101-14Mgt	Fast/High			Fast/High	Slow/Low	Res.
1103Paulsen	Fast/High			Fast/High	Slow/Low	Fast/Low
Freedom	Res.*		Slow/Low	Slow/High	Slow/Low	Res.

Res.	Average Reproductive Speed longer than 30 days (No Adults Ever Observed)
Res.*	Average Reproductive Speed longer than 30 days (Adults Observed)
Slow	21-30 days (significantly longer than Vin-R1 on Colombard control)
Fast	10-17 days (not significantly different than Vin-R1 on Colombard control)
Low	<4 eggs per day per adult (significantly smaller than Vin-R1 on Colombard control)
High	7-15 eggs per day per adult (not significantly different than Vin-R1 on Colombard control)

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Phylloxera Resistant Rootstocks

- Phylloxera are a diverse insect that will change (be selected) when we give it a new host (rootstock)
- **The feeding on all pure American species and their hybrids (rootstocks) is only at the nodosity level**
- Rootstocks with pure American species heritage have a wide variety of resistant responses to this diversity
- Rootstocks with pure American species heritage should never be susceptible to phylloxera feeding

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Nematode Resistant Rootstocks

- Nematodes are even more diverse, so resistance is even more complex

Types of Nematodes

- There are many different types of Nematodes that affect grapes
  - Ectoparasite (live inside root)
    - Root knot nematodes
      - *Meloidogyne incognita*
      - Other *Meloidogyne* spp.
    - Lesion nematode
      - *Pratylenchus vulnus*
    - Citrus nematodes
      - *Tylenchulus semipenetrans*

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Types of Nematodes

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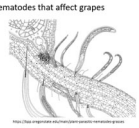
      - *Mesocriconema xenoplax*
    - Stubby root nematode
      - *Paratrichodorus* spp.
    - Pin Nematode
      - *Paratylenchus hamatus*



https://bae.oregonstate.edu/main/plant-parasitic-nematode-guide

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Nematode Resistant Rootstocks

Genotype / Nematode Type	M. incognita Race 3 Root-knot Nematode	M. javanica Root-knot Nematode	Meloidogyne Type Harmony A&C Root-knot Nematode	M. chitwoodi Root-knot Nematode	P. vulnus Lesion Nematode	T. semipenetrans Citrus Nematode	Para. hamatus Pin Nematode	M. xenoplax Ring Nematode	X. americanum Dagger Nematode	X. index Dagger Nematode
101-14Mgt			Very Small		Small		Large	Large		Large
1103Paulsen			Large		Medium		Large	Large		Large
110Richter			Small		Large		Large	Large		Large
140Ruggeri			Small		Large		Medium	Large		Large
Dog Ridge	Very Small	Very Small	Large			Small	Medium	Large	Small	Large
Freedom	Very Small	Very Small	Large	Large	Medium	Large	Small	Medium	Medium	Very Small
Harmony	Very Small	Very Small	Large	Large	Large	Large	Large	Large	Large	Medium
Kober 5BB			Very Small		Medium		Small	Large		Large
Ramsey	Very Small	Very Small	Large	Large	Medium	Medium	Large	Large	Large	Small
Schwarzmann	Large	Small	Large		Large	Large	Large	Medium	Medium	Small
St. George	Large		Large		Medium		Medium	Large		Large
Teleki 5C	Medium	Small	Large		Large	Large	Medium	Medium	Large	Small
VR O39-16	Large	Large	Large		Small	Large	Small	Very Small	Small	Very Small

From Ferris, Zheng, & Walker 2012
Very Small <10% susceptible control, Small 10-30% susceptible control, Medium 30-50% susceptible control, Large >50% susceptible control.

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Phylloxera Resistant Rootstocks

Root Source \ Phylloxera Type	101-L1 (Fol)	StG-L1 (Fol)	101-R1	101-R2	AxR-R1 (Bio B)	Vin-R1 (Bio A)
Colombard	Slow/Low	Res.*	Slow/Low	Slow/High	Fast/High	Fast/High
AxR#1	Slow/High	Fast/High	Fast/High	Fast/High	Fast/High	Res.*
V. berlandieri 9043	Slow/High	Slow/Low	Slow/High	Slow/High	Fast/High	Res.
V. riparia 1411	Fast/High	Fast/High	Slow/High	Slow/High	Fast/High	Fast/High
St. George	Fast/High	Fast/High	Slow/High	Slow/High	Slow/High	Slow/High
V. berlandieri 9031	Slow/Low	Slow/Low	Res.	Res.	Res.	Res.
V. riparia 1437	Res.	Res.	Slow/High	Fast/High	Res.	Res.
V. rupestris Ganzin	Res.	Res.	Slow/Low	Slow/High	Slow/Low	Res.
V. rotundifolia Trayshed	Res.	Res.	Res.	Res.	Res.	Res.
101-14Mgt	Fast/High			Fast/High	Slow/Low	Res.
1103Paulsen	Fast/High			Fast/High	Slow/Low	Fast/Low
Freedom	Res.*		Slow/Low	Slow/High	Slow/Low	Res.

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Nematode Resistant Rootstocks

Genotype	M. incognita Race 3	M. javanica	Meloidogyne Type Harmony A&C	M. chitwoodi	P. vulnus	T. semipenetrans	Para. hamatus	M. xenoplax	X. americanum	X. index
Nematode Type	Root-knot Nematode	Root-knot Nematode	Root-knot Nematode	Root-knot Nematode	Lesion Nematode	Citrus Nematode	Pin Nematode	Ring Nematode	Dagger Nematode	Dagger Nematode
101-14Mgt			Very Small		Small		Large	Large		Large
1103Paulsen			Large		Medium		Large	Large		Large
110Richter			Small		Large		Large	Large		Large
140Ruggeri			Small		Large		Medium	Large		Large
Dog Ridge	Very Small	Very Small	Large			Small	Medium	Large	Small	Large
Freedom	Very Small	Very Small	Large	Large	Medium	Large	Small	Medium	Medium	Very Small
Harmony	Very Small	Very Small	Large	Large	Large	Large	Large	Large	Large	Medium
Kober 5BB			Very Small		Medium		Small	Large		Large
Ramsey	Very Small	Very Small	Large	Large	Medium	Medium	Large	Large	Large	Small
Schwarzmann	Large	Small	Large		Large	Large	Large	Medium	Medium	Small
St. George	Large		Large		Medium		Medium	Large		Large
Teleki 5C	Medium	Small	Large		Large	Large	Medium	Medium	Large	Small
VR O39-16	Large	Large	Large		Small	Large	Small	Very Small	Small	Very Small

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From Ferris, Zheng, & Walker 2012
Very Small <10% susceptible control, Small 10-30% susceptible control, Medium 30-50% susceptible control, Large >50% susceptible control.

Nematode Resistant Rootstocks

- To create more durable nematode resistant rootstocks 2 breeding programs jumped into action
  - USDA Breeding Program
    - RS3 and RS9
      - Ramsey x Schwarzmann
      - Bred for Root-knot Nematode resistance
  - UC Davis
    - GRN1, GRN2, GRN3, GRN4, and GRN5
      - Complex crosses
      - Bred for Dagger and Root-knot Nematode resistance
- These programs were both successful

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Nematode Resistant Rootstocks

- RS3 & RS9 have broad resistance to Root-knot Nematodes
- GRN1 – 5 have broad nematode resistance

Genotype	M. incognita Race 3	M. javanica	Meloidogyne Type Harmony A&C	M. chitwoodi	P. vulnus	T. semipenetrans	Para. hamatus	M. xenoplax	X. americanum	X. index
Nematode Type	Root-knot Nematode	Root-knot Nematode	Root-knot Nematode	Root-knot Nematode	Lesion Nematode	Citrus Nematode	Pin Nematode	Ring Nematode	Dagger Nematode	Dagger Nematode
1103Paulsen			Large		Medium		Large	Large		Large
Freedom	Very Small	Very Small	Large	Large	Medium	Large	Small	Medium	Medium	Very Small
RS-3	Very Small	Very Small	Small	Small	Small		Large	Large		Large
RS-9	Very Small	Very Small	Very Small	Very Small	Medium		Large	Large		Large
UCD GRN1	Very Small		Very Small		Small	Very Small	Small	Very Small		Very Small
UCD GRN2	Very Small		Very Small		Small	Medium	Small	Medium		Very Small
UCD GRN3	Very Small		Very Small		Small	Small	Small	Small		Very Small
UCD GRN4	Very Small		Very Small		Small	Small	Medium	Small		Very Small
UCD GRN5	Very Small		Very Small		Small	Small	Small	Very Small		Very Small

From Ferris, Zheng, & Walker 2012
Very Small <10% susceptible control, Small 10-30% susceptible control, Medium 30-50% susceptible control, Large >50% susceptible control.

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Nematode Resistant Rootstocks

- RS3 & RS9 have broad resistance to Root-knot Nematodes
- GRN1 – 5 have broad nematode resistance
- As these rootstocks are made from pure American species hybrids, they are also all phylloxera resistant

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Outline

- Types of Nematodes and Their Damage
- Phylloxera and Their Damage
- Resistant Rootstocks
- **Other Ways to Control Soil Pests**

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Phylloxera Controlling Soil Pests

- Phylloxera are not a very durable insect
  - Phylloxera have gone all in on maxing out reproduction
  - To the detriment of long-term survival of an individual bug

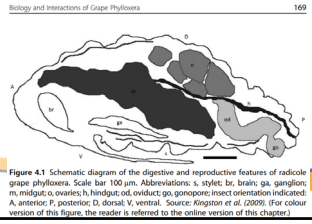

Figure 4.1 Schematic diagram of the digestive and reproductive features of radicole grape phylloxera. Scale bar 100 µm. Abbreviations: s, stylet; br, brain; ga, ganglion; m, midgut; o, ovaries; h, hindgut; od, oviduct; go, gonopore; insect orientation indicated: A, anterior; P, posterior; D, dorsal; V, ventral. Source: *Kingston et al. (2009).* (For colour version of this figure, the reader is referred to the online version of this chapter.)

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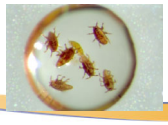
Phylloxera Controlling Soil Pests

- This leave phylloxera open to some simple control methods
  - Unlike most insects, phylloxera don't have an external waterproof layer or mechanism
  - An original control method used in France during the first phylloxera outbreak was flooding a field for 40 days and nights (groundwater recharge)
  - Flood irrigation will also help keep phylloxera numbers down

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Nematode Resistant Rootstocks

- RS3 & RS9 have broad resistance to Root-knot Nematodes
- GRN1 – 5 have broad nematode resistance

Genotype	M. incognita Race 3	M. javanica	Meloidogyne Type Harmony A&C	M. chitwoodi	P. vulnus	T. semipenetrans	Para. hamatus	M. xenoplax	X. americanum	X. index
Nematode Type	Root-knot Nematode	Root-knot Nematode	Root-knot Nematode	Root-knot Nematode	Lesion Nematode	Citrus Nematode	Pin Nematode	Ring Nematode	Dagger Nematode	Dagger Nematode
1103Paulsen			Large		Medium		Large	Large		Large
Freedom	Very Small	Very Small	Large	Large	Medium	Large	Small	Medium	Medium	Very Small
RS-3	Very Small	Very Small	Small	Small	Small		Large	Large		Large
RS-9	Very Small	Very Small	Very Small	Very Small	Medium		Large	Large		Large
UCD GRN1	Very Small		Very Small		Small	Very Small	Small	Very Small		Very Small
UCD GRN2	Very Small		Very Small		Small	Medium	Small	Medium		Very Small
UCD GRN3	Very Small		Very Small		Small	Small	Small	Small		Very Small
UCD GRN4	Very Small		Very Small		Small	Small	Medium	Small		Very Small
UCD GRN5	Very Small		Very Small		Small	Small	Small	Very Small		Very Small

From Ferris, Zheng, & Walker 2012

Very Small <10% susceptible control, Small 10-30% susceptible control, Medium 30-50% susceptible control, Large >50% susceptible control.

Phylloxera Controlling Soil Pests

- Insecticide control over phylloxera can be achieved with several different chemicals
  - Spirotetramat (Movento)
  - Imidacloprid (Admire Pro)
  - Clothianidin (Belay)
  - Dinotefuran (Venom)
  - Thiamethoxam (Platinum)
- Many of these insecticides are used to target other insects
  - Thus, you can get phylloxera control while controlling mealybugs or sharpshooters

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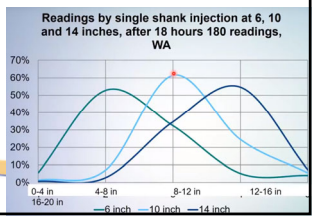
Nematode Control Pre-planting

- Fumigation
  - 1,3-Dichloropropene (Telone II)
    - Limitation on use by regulatory agencies
  - Metam Sodium
    - Does not spread effectively inside soil profile



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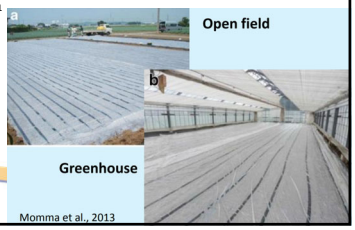
Nematode Control Pre-planting

- Anaerobic soil disinfestation (ASD)
  - Creates anaerobic conditions in the soil
    - Organic matter incorporated into soil
      - Wheat bran, rice bran, molasses – C:N ratio of 30:1
    - Covered with O_2 impenetrable tarp
    - Irrigated until soil profile is saturated
  - Nematodes and other pests suffocate



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Nematode Control Pre-planting

- Fumigation and ASD can both reduce nematode populations prior to planting
- But both fumigation and ASD have broad spectrum activity that kill both pests and beneficial organisms in the soil

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Nematode Control Post-planting

- After planting fumigation and ASD cannot be used
- Chemical control
  - **Spirotetramat**
- Biological Control
  - ***Myrothecium verrucaria***

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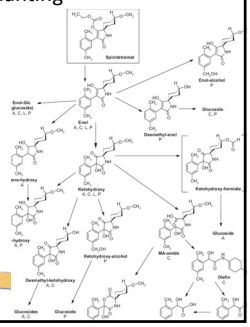
Nematode Control Post-planting

- Spirotetramet (Movento)
  - Does have nematicidal properties
  - Understanding how Spirotetramet moves within the plant is important
  - After entering the leaves it is changed into an Enol form
  - This Spirotetramet Enol can move within the plant vasculature



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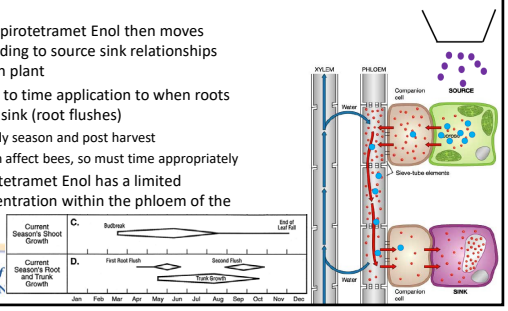
Nematode Control Post-planting

- The Spirotetramet Enol then moves according to source sink relationships within plant
- Need to time application to when roots are a sink (root flushes)
  - Early season and post harvest
  - Can affect bees, so must time appropriately
- Spirotetramet Enol has a limited concentration within the phloem of the plant



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Nematode Control Post-planting

- *Myrothecium verrucaria* strain AARC-0255 (Ditera DF)
  - A fungus that is a highly potent cellulose decomposer
  - It is specific to targeting plant parasitic nematodes
  - Causes paralysis to nematode general movement and in their stylet
    - In culture
  - Approved for organic production
  - Video
    - https://www.youtube.com/watch?v=gLxKqIvGg0M

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Nematode Controlling Soil Pests

- Pre-plant options for controlling nematodes can be highly effective at reducing nematode populations
- However, these treatments can also have negative effects on soil health
- Post-plant options for controlling nematodes can be effective, but need to be well timed
- Newer nematode-resistant rootstocks have broader resistance than current rootstocks

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Thank You

- Questions?

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