Grape Phylloxera in California and the World

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LAB AND FIELD
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Acknowledgements

ROOTSTOCKS
- California Grape Rootstock Improvement Commission
- NT, FT, GV Improvement Advisory Board/ CTGC
- American Vineyard Foundation / California Competitive Grant Program for Research in Viticulture and Enology

PD
- CDFA PD/GWSS Board
- American Vineyard Foundation
- CTGC/CRMB
- USDA-APHIS PD Program

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Phylloxera
- “North” American insect
- Imported to Europe in 1850s
- Initiated rootstock breeding - most rootstocks are >100yrs old
- Phylloxera spread most readily on plant materials, and blown as crawlers and winged forms
- Feed on leaves of rootstocks and roots of vinifera
Grape Phylloxera

- Native Range — from Quebec to Venezuela.
- *Vitis* species were imported into Europe in the mid-1800s to breed for resistance against powdery and downy mildew, and black rot.
- Phylloxera came along.

Phylloxera Life Cycle

- Asexual/clonal reproduction on the roots and leaves.
- A rarely seen “bridging” sexual phase.
- New York phylloxera have relatively few generations, some isolates feed poorly on *vinifera* roots.
- California phylloxera don’t feed on leaves.
<table>
<thead>
<tr>
<th>Phylloxera origin</th>
<th>Original host</th>
<th>New host</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Northeast</td>
<td>V. riparia</td>
<td>V. vinifera</td>
</tr>
<tr>
<td>US Southeast</td>
<td>V. vulpina</td>
<td>V. vinifera</td>
</tr>
<tr>
<td></td>
<td>V. aestivalis</td>
<td></td>
</tr>
</tbody>
</table>

Data from Winkler et al. 1974
Field Populations

- Temperature
- Phylloxera/g dry weigh root

Stockton, CA
Phylloxera

- Feed on root tips and mature roots (nodosities vs. tuberosities). Do all rootstocks support root tip feeding?
- They kill vines by creating wounds that are attacked by opportunistic saprophytic fungi.
- Recent phylloxera-related damage on rootstocks seems to be the result of these secondary pathogens.
Phytophthora, Fusarium, Alternaria, Rhizoctonia, Trichoderma, Macrophomina, Phaeoacremonium

Phylloxera & vineyard management

% root rot

Organic

Conventional

Phylloxera/g root dry weight
Introduction of Phylloxera into California

- Settlement from Mexico began in 1769
- Settlement from eastern USA began about 1850 (post Gold Rush)
- Potted plants of American Hybrids arrived in late 1840s
- 1860s - Catawba bug identified (foliar phylloxera galls)
- 1870s - Viticulture based primarily on the Mission grape (Criolla)

- 1873 - Phylloxera detected on roots and killing vines
- 1880s - Phylloxera widely distributed
- Phylloxera moved very quickly - most likely on rooted dormant plants - bare roots
- 1880s - imported cuttings of *riparia* and *rupestris* from Mississippi River Valley (Midwest USA) for use as rootstocks
Introduction of Phylloxera into California

- 1880s - Phylloxera Board initiated as part of California State Viticultural Board
- 1881 - First warnings of dangers associated with uncontrolled importations from Europe and Eastern USA
- 1900s - Rootstock experimentation begins with varieties brought from France

George Hussmann

- USDA rootstock trials.
- Tested 102 rootstocks in plots located across Calif.
- First report in 1915
- 1930 was focused on: AXR#1, AXR#2, 1202C, Lenoir, St. George, Riparia Gloire, 420A Mgt, 161-49C, 3306C, 3309C, 1616C, 1613C, Dog Ridge and Salt Creek (Ramsey)
Harry Jacob

- UC Davis rootstock and propagation studies began in 1925
- Tested a broad set of rootstocks on 99 sites in 17 counties - many were sites from Hussmann and Bioletti

Lloyd Lider

- Lider replaced Jacob and wrote up these long-term rootstock trials; emphasis on phylloxera (1958) and nematodes (1960)
- Concluded AXR#1 was well-suited to many sites and provided a general solution with good yields and quality
- “It is understood that in very dry, shallow soils and in areas where phylloxera can be serious they (AXR#1) may do poorly or even fail.”
AXR#1

- *vinifera* ‘Aramon’ x *rupestris* ‘Ganzin’
- Known to have failed in France, Italy and South Africa
- Trials were planted in phylloxerated areas, but no susceptible controls
- The aim of the trials was to exclude rootstocks and make general recommendations

AXR#1 in 1970s California Vineyard Expansion

- 75% of North Coastal vineyards (Napa, Sonoma, Mendocino)
- Many vineyards went in on “own-roots” in the Central Valley and Central Coast
- AXR#1 vineyards failing in 1984, Central Coast at about the same time
- It takes about 15 years to detect phylloxera damage
- Wine quality suffers first – low potassium one of best indicators
Post AXR#1 Era Problems

- No current rootstock information
- Many vineyards went in on “own-roots” in the Central Valley and Central Coast
- Graft compatibility issues with field selections - vineyards failed

Rootstock Use in 1990

- 3309C, 110R, 5C, and St. George in the Coastal Valleys
- Freedom in the Central Valley
- O39-16 for fanleaf degeneration sites
Rootstock Use in 2006

- Primary Rootstocks for Coastal Valleys - 101-14Mgt, 1103P, 3309C, 420A Mgt
- Central Valley - Freedom, Harmony, Ramsey (interest in less vigorous rootstocks too on fertile sites)
- O39-16 for fanleaf degeneration
Minirhizotron observations
Bauerle et al. 2004

Emergence traps

Oakville Field Station
Napa, 101-14 Mgt
One-generation assay

- 10 eggs per root
- Roots<1 year, field collected
- Two roots per dish
- Parafilm sealed
- 21 days, dark 24°C

[new eggs+crawlers]

20 starting eggs per dish

- Survival
- Development
- Eggs per female

### (2004) One generation population increase

<table>
<thead>
<tr>
<th></th>
<th>Type A eggs</th>
<th>Type B eggs</th>
<th>101-Phyllox eggs</th>
<th>Signif.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teleki 5C</td>
<td>1.4</td>
<td>4.3</td>
<td>1.6</td>
<td>NS</td>
</tr>
<tr>
<td>1103 P</td>
<td>0.2</td>
<td>0.0</td>
<td>0.3</td>
<td>NS</td>
</tr>
<tr>
<td>101-14 Mgt</td>
<td>0.0</td>
<td>0.0</td>
<td>4.7</td>
<td>**</td>
</tr>
<tr>
<td>V. vinifera</td>
<td>11.7</td>
<td>15.1</td>
<td>2.1</td>
<td>**</td>
</tr>
<tr>
<td>AXR#1</td>
<td>1.6</td>
<td>9.2</td>
<td>4.5</td>
<td>NS</td>
</tr>
<tr>
<td>Rip Gloire</td>
<td>0.3</td>
<td>0.0</td>
<td>7.1</td>
<td>**</td>
</tr>
<tr>
<td>Rup St G</td>
<td>6.3</td>
<td>4.5</td>
<td>9.8</td>
<td>NS</td>
</tr>
</tbody>
</table>
One-generation increase on nodosities

1. Host of origin response
2. Lots of parentage variability
3. Types A and B differ from 101-14 phylloxera
4. *V. vinifera* resistance trait
5. American species susceptibility trait
6. No tuberosities

**Questions**

### Fungal virulence

Soils from vineyard blocks; Lab bioassay with *V. vinifera* roots; Duration 5 weeks

<table>
<thead>
<tr>
<th>County</th>
<th>Rootstock</th>
<th>Damaged</th>
<th>Not damaged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mendocino</td>
<td>101-14</td>
<td><strong>26.5 ± 7.1</strong></td>
<td>6.1 ± 1.7</td>
</tr>
<tr>
<td>Sonoma</td>
<td>101-14</td>
<td><strong>28.2 ± 8.8</strong></td>
<td>3.6 ± 0.7</td>
</tr>
<tr>
<td>Sonoma</td>
<td>Teleki 5C</td>
<td><strong>28.4 ± 15.0</strong></td>
<td>6.1 ± 2.9</td>
</tr>
<tr>
<td>Napa</td>
<td>101-14</td>
<td><strong>29.8 ± 15.0</strong></td>
<td>no vines</td>
</tr>
<tr>
<td>Napa</td>
<td>Teleki 5C</td>
<td><strong>47.2 ± 19.8</strong></td>
<td>6.6 ± 2.9</td>
</tr>
</tbody>
</table>

% Necrosis ± 95%CL

- Mendocino: 26.5 ± 7.1%
- Sonoma: 28.2 ± 8.8%
- Sonoma Teleki 5C: 28.4 ± 15.0%
- Napa: 29.8 ± 15.0%
- Napa Teleki 5C: 47.2 ± 19.8%

Fungi: 55% Virulence

Fungi: 20% Virulence
Nodosity host races & probing

Why?
1. Misidentified rootstocks?
2. Nematodes, soil, management?
3. Change in phylloxera?
4. Intense nodosity damage? No
5. Probing and fungus?

Host race
Probing
Probing

Parable of the hungry aphid

Do phylloxera probe?
Visualizing probe wounds?
Probing Field Test (2004)

- Control
- Eggs alone
- Fusarium alone
- Wounds alone

<1%

Lab Results

- Control
- Fusarium alone, very low
- Wounds alone
What we think we know

<table>
<thead>
<tr>
<th>AXR#1 failure site</th>
<th>Fungi &amp; phylloxera remain.</th>
<th>Phylloxera nodosities</th>
<th>Probing</th>
<th>Root necrosis</th>
<th>Vine death</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New rootstocks planted</td>
<td></td>
<td></td>
<td>Fungal infection</td>
<td></td>
</tr>
</tbody>
</table>

2005-2006

1. Probing experiments
2. Bioassays: host races
3. DNAs (host, season, tissue races, sex)
4. Surveys

Criticisms
- Site specificity: **not tested yet.**
- Nodosity host race: **minimal data.**
- Probing: **circumstantial.**
- Root necrosis in these circumstances: **only hypothesized.**
SSR Markers for Phylloxera

- We have recently developed SSR markers for phylloxera – 7 work very well; more could be developed. 4 available from Australian work.
- Able to genotype and conduct host adaptation studies now.

Dendrogram presenting genetic similarity among 32 phylloxera populations from allele size differences at 7 SSR loci.
DNA host races (2004-2005)

(Ten SSR primers; Lin et al. in press)

DNA host races (2005)

5C adjacent to AXR#1 from original planting
DNA host races

1. Lots of variability (Why?)
2. Host race DNA distinctions
3. Fine differences

Questions

Conclusions

- Phylloxera form nodosities on resistant rootstocks and species
- Rootstocks are not failing
- Phylloxera are diverse
- Populations crash in the Winter with asexual/clonal reproduction rapid changes can occur
Questions

1. Nodosity, tuberosity genotypes?
2. Seasonal genotypes?
3. Role of the sexual cycle - above and/or below ground?

Why interesting?

- Understand durability of rootstocks
- Limitations

Thanks!