Rootstock Selection

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Rootstocks

- “There are often many good, or at least decent choices for a rootstock variety at a site. There are also many bad choices for a rootstock variety at a site. The goal is to avoid the bad choices and understand why the choice you made is good not perfect.”
  – Andy Walker

Why Rootstocks

- What rootstock should I use?

Why Rootstocks

- What rootstock should I use?

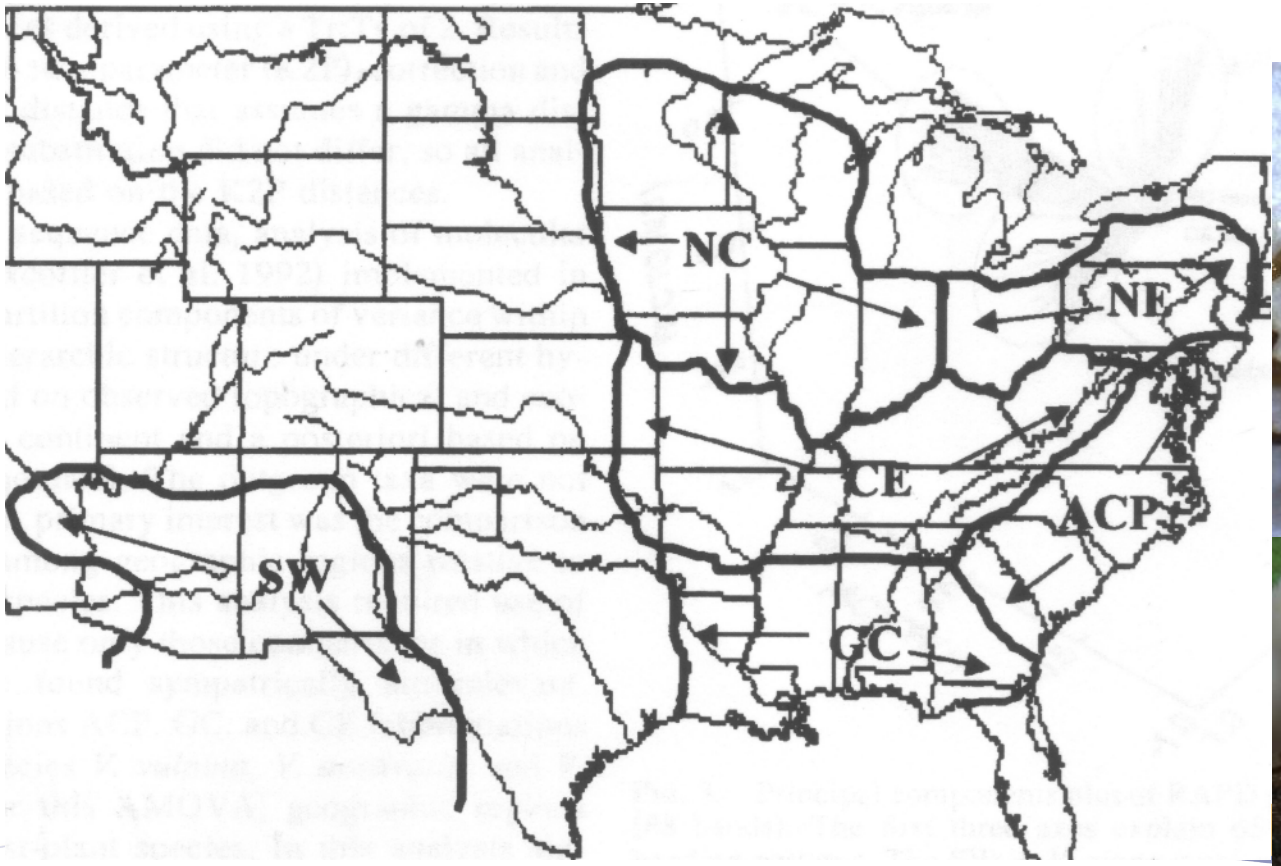
- Why do we use rootstocks?

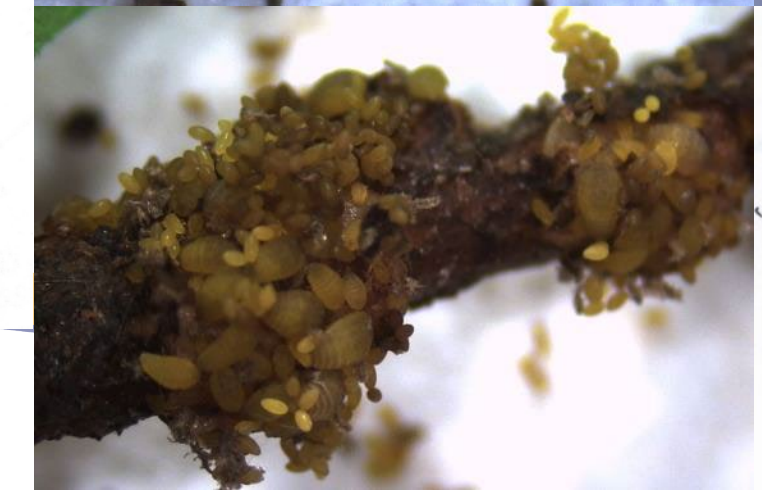
Why Rootstocks

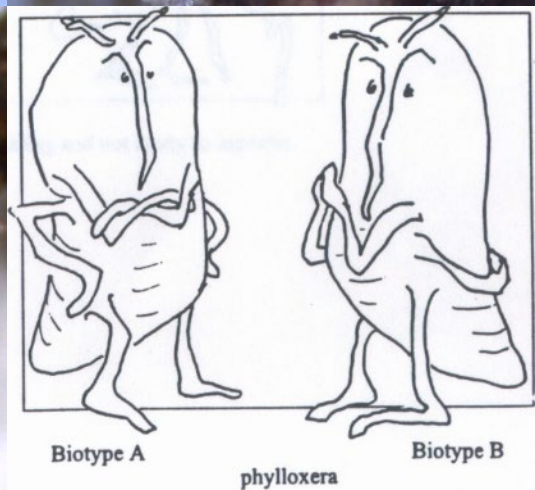
- What rootstock should I use?
- Why do we use rootstocks?
- Why did we start using rootstocks?

Phylloxera

- Phylloxera are an aphid like insect native to the Eastern and Southwestern US







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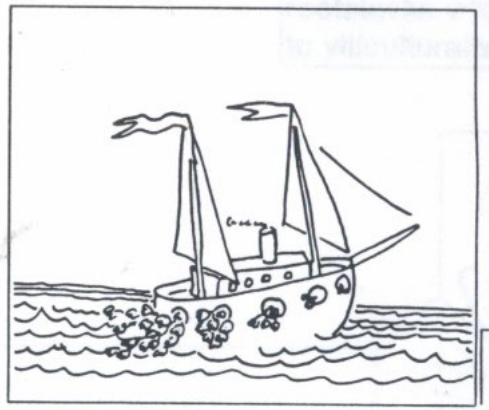
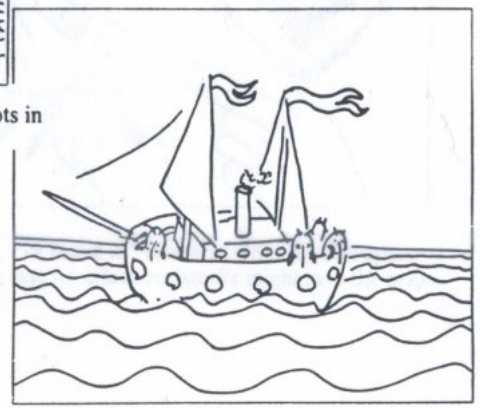
Phylloxera

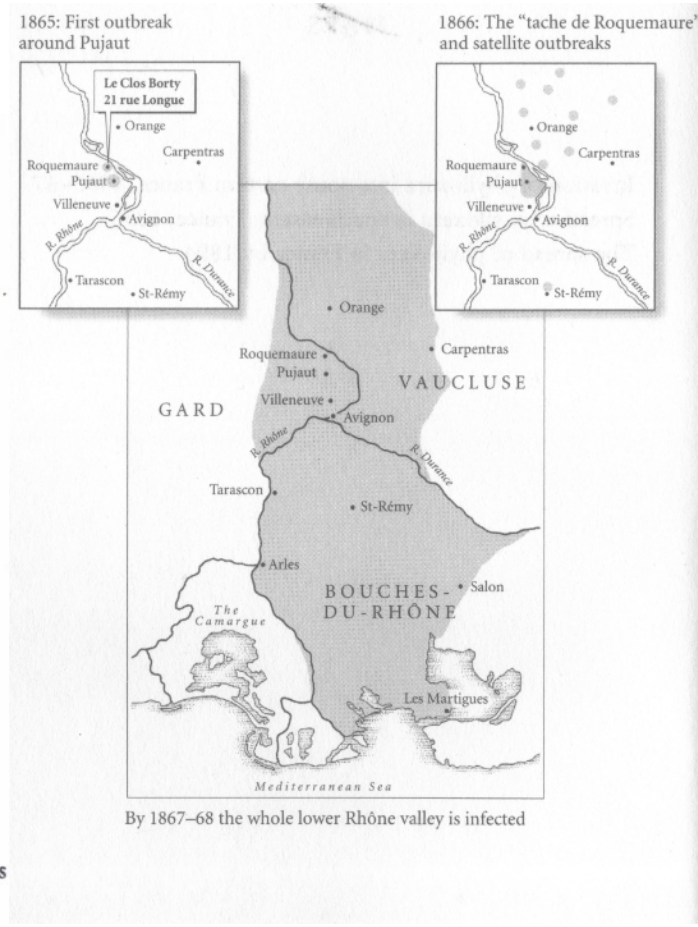
- They were accidentally introduced to Europe and destruction followed



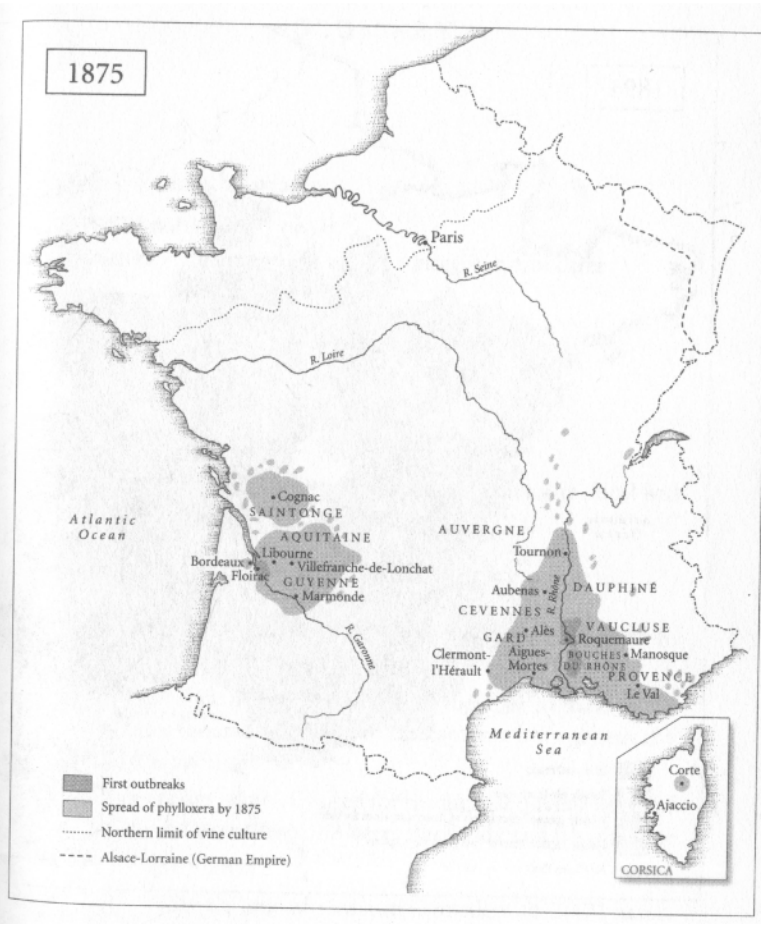
European grapes seeking a place to set down fresh roots in the new world.



Phylloxera pilgrims crossing the ocean to prey at the roots of the European grape

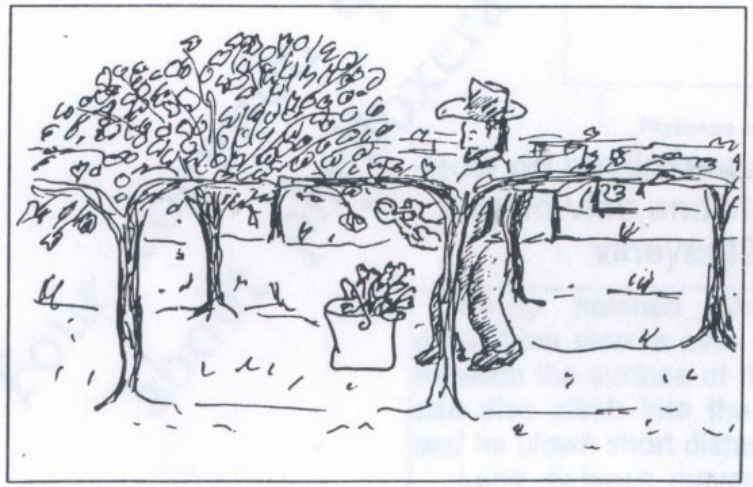


By 1867–68 the whole lower Rhône valley is infected



Phylloxera

- They were accidentally introduced to Europe and destruction followed
- Within 30 years most French vineyards were affected
- The French government looked for a solution
- The answer was rootstocks



Leo Laliman observing survival of American vines in a field of dead European vines

"Eureka, I've found it!" shouted Gaston Bazille upon realizing that American rootstocks might save the grape industry.

Phylloxera

- Why?

Observed on
American Vitis species

Observed on
Vitis vinifera

Leaf Gals

Nodosity

Tuberosity

Can devigorate plant with large enough populations of phylloxera

Allows for the infection of secondary soil fungi that lead to root death and plant death

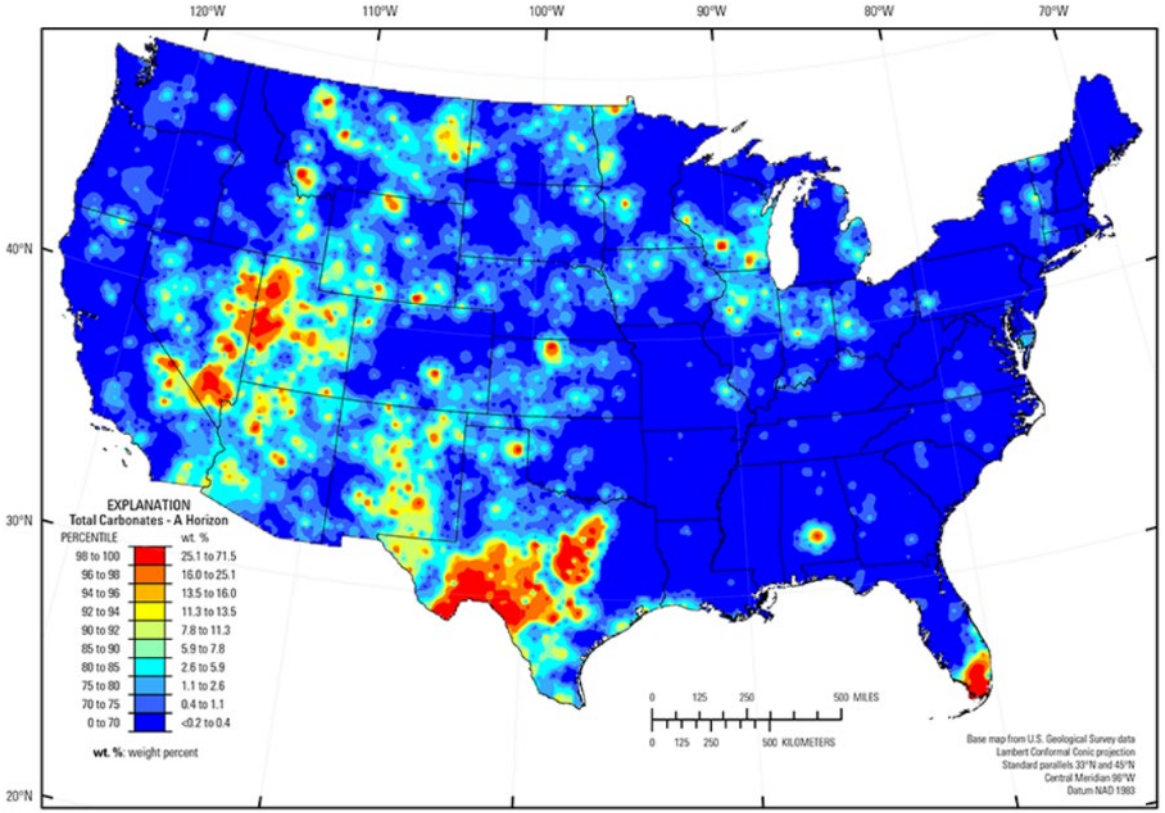
Next Problem

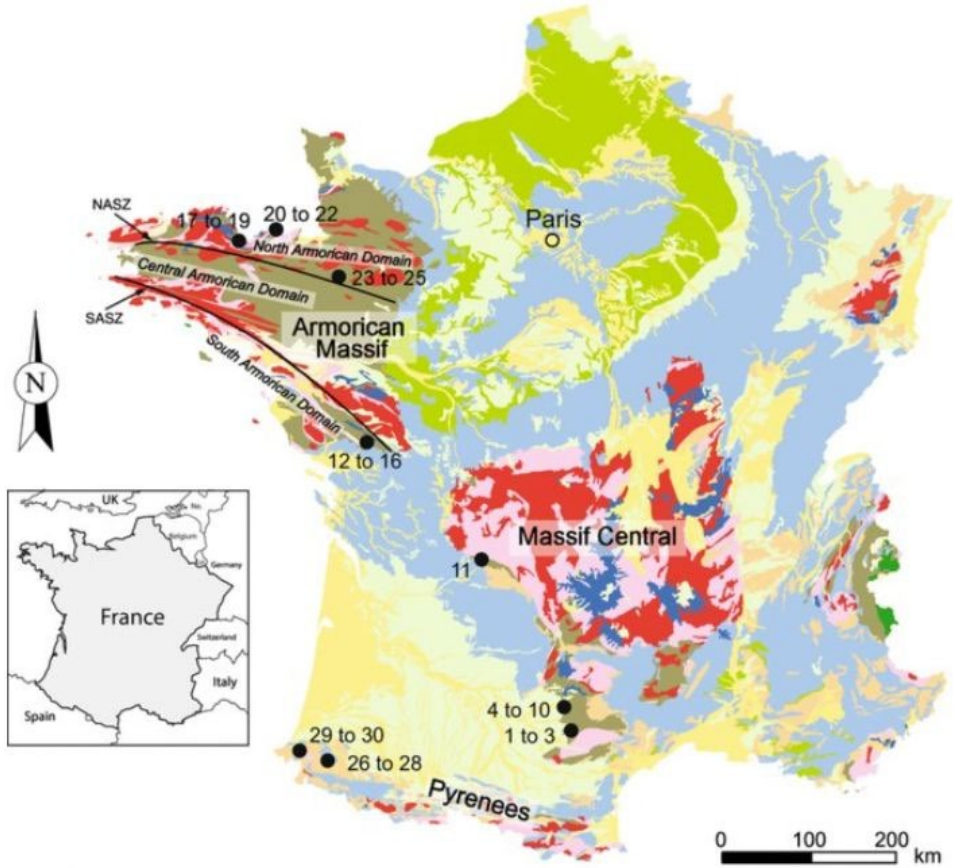
- American Vitis species were selected as rootstocks… Problem solved
  - Well no
  - American Vitis species that rooted easily were intolerant of lime leading to chlorosis
    - Vitis riparia
    - Vitis rupestris
  - Needed breeding to get rooting and lime tolerance into one rootstock
    - Vitis berlandieri for lime tolerance

https://www.lodigrowers.com

Next Problem

- Limestone soils are virtually non-existent in US wine growing





https://pubs.usgs.gov/sir/2017/5118/sir20175118_element.php?el=909

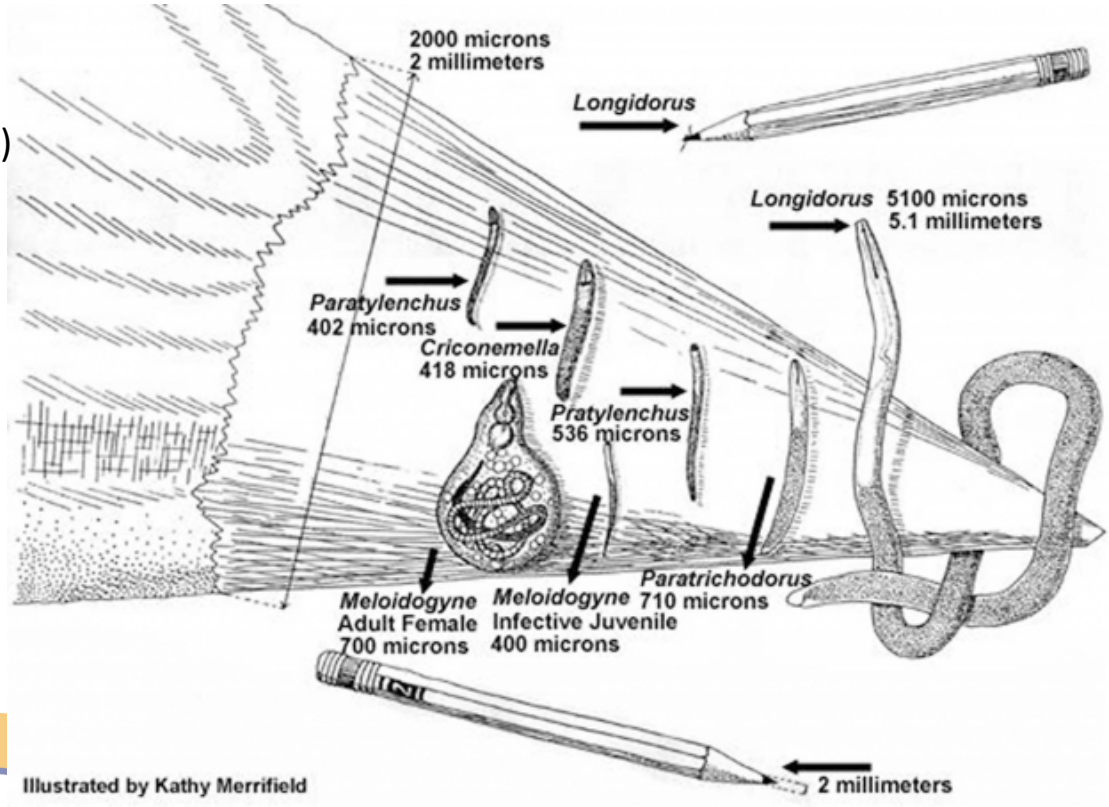
https://link.springer.com/article/10.1007/s12665-018-7549-5

Problems to Solve

- Soil Pests
  - Phylloxera
  - Nematodes
- Effects on Scion
  - Vigor
- Soil Adaptation
  - Lime (in Europe)
  - Soil type and depth

Nematode Resistance

- Nematodes are the second major soil pest
  - Nematodes are many different species with multiple feeding types
    - Endoparasite
      - Root knot nematodes:
        - » Meloidogyne incognita, M. javanica, M. arenaria, & M. hapla)
      - Lesion Nematode
        - » Pratylenchus vulnus
      - Citrus Nematode
        - » *Tylenchulus semipenetrans*
    - Ectoparasite
      - Dagger Nematode
        - » *Xiphinema index & X. americanum*
      - Ring Nematode
        - » *Mesocriconema* (*Criconemella*) *xenoplax*



Nematode Resistance

- As there are many nematodes there are many different levels of 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
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 Resistance

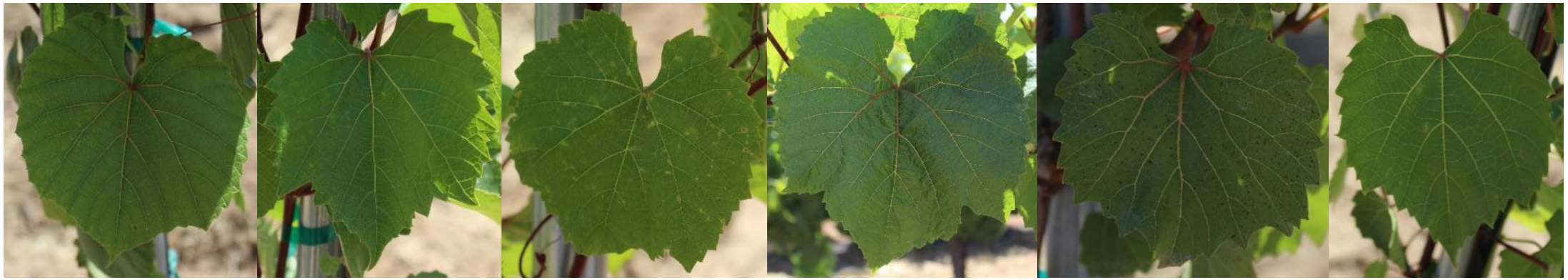
- There are a few “new” rootstocks with broad nematode resistance

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
101-14Mgt			Very Small		Small		Large	Large		Large
1103Paulsen			Large		Medium		Large	Large		Large
Freedom	Very Small	Very Small	Large	Large	Medium	Large	Small	Medium	Medium	Very Small
VR O39-16	Large	Large	Large		Small	Large	Small	Very Small	Small	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.

Nematode Resistance

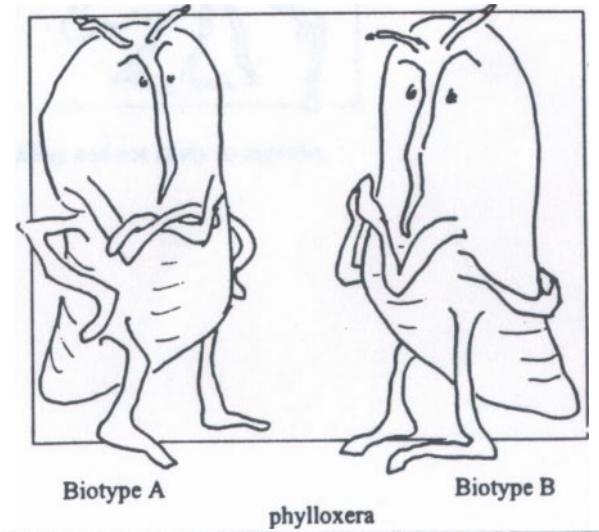
- It is important to know what types of nematodes your vineyard has
  - And what types are common in your region
- Make sure the rootstock you select can handle what is in your soil
  - And hopefully everything in your region as well

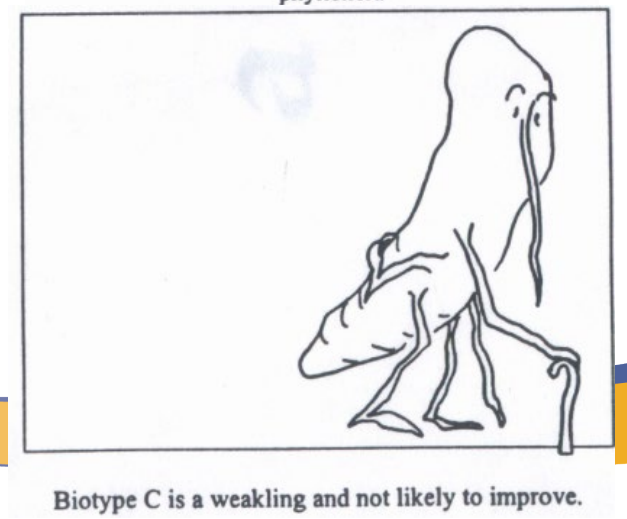


Pest Adaptation

- Both phylloxera and nematodes are living creates that can adapt and change to the pressures we put on them
  - Meloidogyne pathotypes Harmony A & C nematodes
  - Peach root-knot nematode (*Meloidogyne floridensis*)
  - Biotype A, then Biotype B, now 101-14 adapted phylloxera
    - Best way to prevent (slow) adaptation is to use a variety of rootstocks

Genotype	M. incognita Race 3	Meloidogyne Type Harmony A&C
Nematode Type	Root-knot Nematode	Root-knot Nematode
Dog Ridge	Very Small	Large
Freedom	Very Small	Large
Harmony	Very Small	Large
Ramsey	Very Small	Large

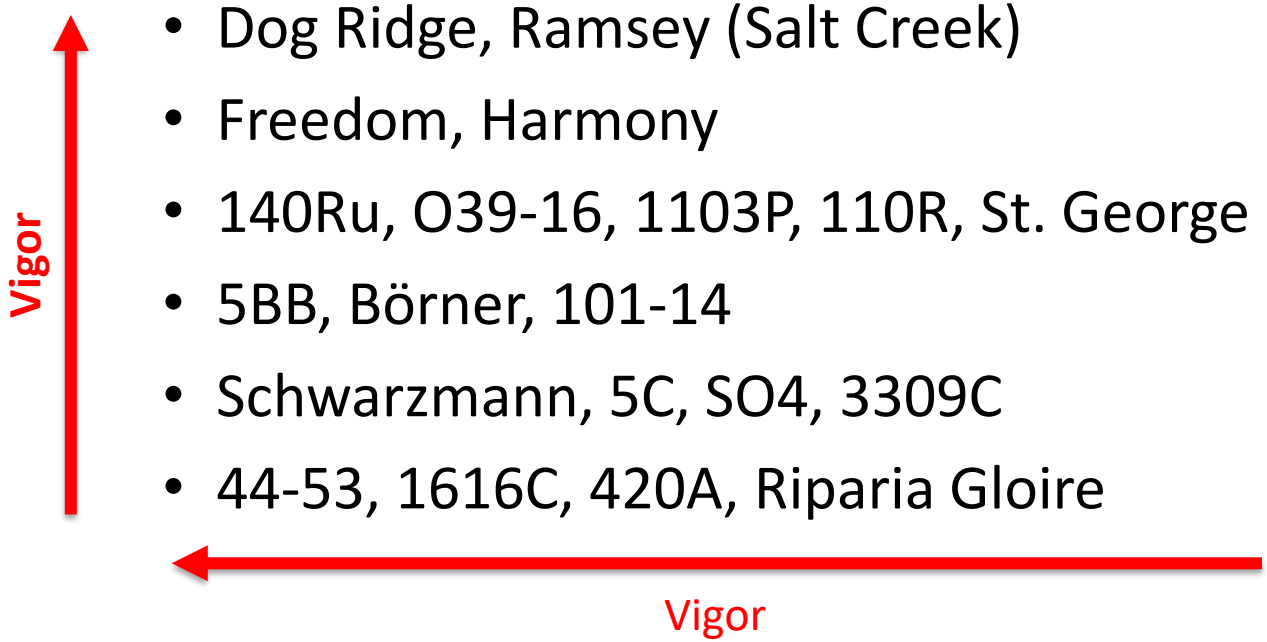




Soil Adaptation

- Pests are not the only thing rootstocks have to deal with
- Rootstocks are also the interaction point between the plant and the soil
- This is seen in obvious way
  - Adaptation to soils with lime
- This can also be seen in more subtle ways
  - Vigor

Vigor



- Dog Ridge, Ramsey (Salt Creek)
- Freedom, Harmony
- 140Ru, O39-16, 1103P, 110R, St. George
- 5BB, Börner, 101-14
- Schwarzmann, 5C, SO4, 3309C
- 44-53, 1616C, 420A, Riparia Gloire

Vigor

- Linked to parentage
- Vitis riparia
  - Rocky Mountains to Atlantic Ocean from Texas to Canada
  - Riparian habitats – alluvial soils, climbs in trees and shrubs
  - Shallow roots, tolerant to phylloxera, susceptible to lime, easy to propagate
  - Induces lower vigor, hastens maturity
  - Example: Riparia Gloire

Vigor

- Linked to parentage
- Vitis rupestris
  - Texas to Tennessee, but rare now (southern Missouri)
  - Deep roots, tolerant to phylloxera, variable nematode resistance, variable lime tolerance, easy to propagate
  - Induces vigor in scion, but not drought tolerant on shallow soils
  - Example: St. George

Vigor

- Linked to parentage
- Vitis berlandieri
  - Texas on Limestone soils
  - Deeper soils between ridges, climbs fences, shrubs and trees
  - Deep rooted, with some drought tolerance
  - Variable between phylloxera tolerance and resistance, good lime tolerance, hard to propagate

Vigor

- Linked to parentage
- Vitis x champinii (Vitis candicans x Vitis rupestris)
  - Texas on eastern Edward's plateau (limestone soils)
  - Deep roots, lime tolerance, resists nematodes, moderate phylloxera resistance, difficult to propagate
  - Induces high vigor in scion
  - Examples: Salt Creek (Ramsey) and Dog Ridge

Vigor

- Very High
  - Dogridge – Vitis champinii
  - Ramsey (Salt Creek) – Vitis champinii
- High
  - Freedom – Vitis solonis x Vitis champinii
  - Harmony – Vitis solonis x Vitis champinii

Vigor

- Medium to High
  - 140 Ru – Vitis berlandieri x Vitis rupestris
  - 039-16 – Vitis vinifera x Vitis rotundifolia
  - 1103P – Vitis berlandieri x Vitis rupestris
  - 110R – Vitis berlandieri x Vitis rupestris
  - St. George – Vitis rupestris
- Medium
  - 5BB – Vitis berlandieri x Vitis riparia
  - Börner – Vitis riparia x Vitis cinerea (Vitis berlandieri is a type of Vitis cinerea)
  - 101-14 – Vitis riparia x Vitis rupestris

Vigor

- Low to Medium
  - Schwarzmann – Vitis riparia x Vitis rupestris
  - 5C – Vitis berlandieri X Vitis riparia
  - SO4 – Vitis berlandieri X Vitis riparia
  - 3309C – Vitis riparia x Vitis rupestris
- Low
  - 1616C – Vitis longii X Vitis riparia
  - 420A – Vitis berlandieri X Vitis riparia
  - Riparia Gloire – Vitis riparia

Vigor

- What level of vigor do you want?
  - What level of vigor does your site have
    - Soil fertility
    - Soil water holding capacity
    - Soil depth
  - Inverse relationship between site vigor and rootstock vigor
    - High site vigor = low rootstock vigor
    - Low site vigor = high rootstock vigor
  - What are your production goals
    - High quantity = higher vigor
    - High quality = controlled vigor

Other Scion Effects

- Nutrient uptake
  - Nutrient uptake from the soil is controlled by your rootstock

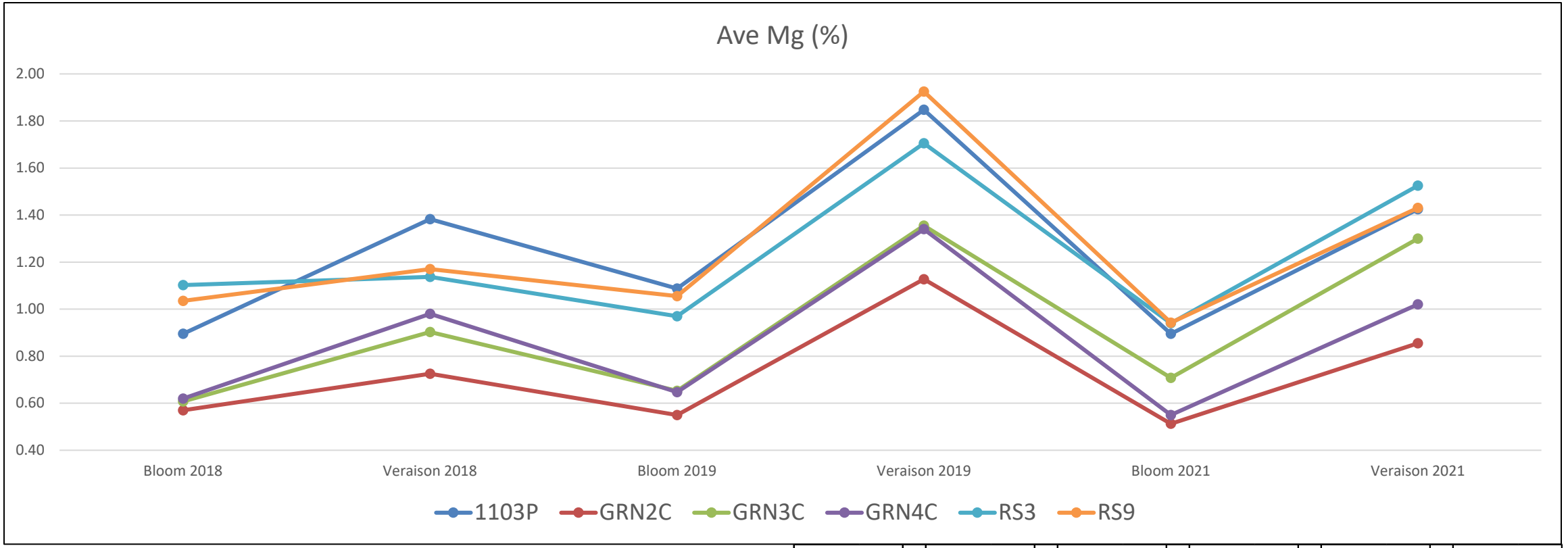
Rootstock	Effect
101-14	N,K: med-high P,Mg,Ca: low Zn: med
1103P	N: med-high P,Mg: high K,Zn: low-med
110R	N: med P: high K: low-med Mg,Zn: med
140Ru	N: med-high P,Mg: high K: low
1616C	N: low K: med-high

Rootstock	Effect
3309C	N: med-high P,Ca: low K,Mg,Zn: med
420A	N,P,K: low Mg: med Zn: low-med
5BB	N: med-high P,K,Zn: med Ca,Mg: med-high
5C	N: low P,K: med Mg: med-high Zn: low-med
99R	P: med K: high Mg: med

Rootstock	Effect
Dogridge	N,P: high K: med Zn: low
Freedom	N,P,K: high Mg: med Zn,Mn: low
Harmony	N: low P: med K: high Zn: low-med
O39-16	N,K: high P: low-med Zn: low
Riparia Gloire	N,P: Low K,Mg: Low-med

Rootstock	Effect
Salt Creek (Ramsey)	N,P: high K: med-high Zn,Mn: low
Schwarzmann	N,P: med K: med-high Mg: low
SO4	N: low-med P:med K: med-high Mg:med
St. George	N: high P: low on low-P soil, high on high-P soil K: high

Nutrient Effects



Bloom 2018		Veraison 2018		Bloom 2019		Veraison 2019		Bloom 2021		Veraison 2021	
Rootstock	Group	Rootstock	Group	Rootstock	Group	Rootstock	Group	Rootstock	Group	Rootstock	Group
RS3	A	1103P	A	1103P	A	RS9	A	RS9	A	RS3	A
RS9	AB	RS9	B	RS9	AB	1103P	A	RS3	A	RS9	AB
1103P	B	RS3	BC	RS3	B	RS3	A	1103P	A	1103P	AB
GRN4C	C	GRN4	CD	GRN3	C	GRN3	B	GRN3C	B	GRN3C	B
GRN3C	C	GRN3	D	GRN4	C	GRN4	B	GRN4C	C	GRN4C	C
GRN2C	C	GRN2	E	GRN2	D	GRN2	B	GRN2C	C	GRN2C	C

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Nutrient Effects

- Why nutrient uptake matters
- Magnesium was low enough in GRN2, GRN3, and GRN4 to start seeing deficiency symptoms

Soil Adaptation

- Rootstocks also need to deal with any issues that your soil (or irrigation water) throw at them
  - Salinity (E.C.) can be an issue in many growing region in California

Rootstock	Salinity Tolerance
Salt Creek (Ramsey)	High
140Ru	Med-high
1616C	Med-high
St. George	Med-high
Schwarzmann	Med-high

Rootstock	Salinity Tolerance
Dogridge	Med-high
110R	Med
Riparia Gloire	Med
5C	Med
5BB	Med

Rootstock	Salinity Tolerance
99R	Med
1103P	Med
101-14	Med
O39-16	Low-med
SO4	Low-med

Rootstock	Salinity Tolerance
3309C	Low-med
Harmony	Low-med
420A	Low-med
Freedom	Low-med

Soil Adaptation

- Rootstocks also need to deal with any issues that your soil (or irrigation water) throw at them
  - Lime containing soils are limited in California

Rootstock	Lime Tolerance
420A	Med-high
5BB	Med-high
140Ru	Med-high
Salt Creek (Ramsey)	Med
SO4	Med

Rootstock	Lime Tolerance
Harmony	Med
Freedom	Med
110R	Med
5C	Med
99R	Med

Rootstock	Lime Tolerance
1103P	Med
St. George	Med
Schwarzmann	Med
Dogridge	Med
3309C	Low-med

Rootstock	Lime Tolerance
101-14	Low-med
1616C	Low-med
O39-16	Low
Riparia Gloire	Low

Soil Adaptation

- Rootstocks also need to deal with any issues that your soil (or irrigation water) throw at them
  - Drought is part of Life in California

Rootstock	Drought Tolerance
110R	High
140Ru	High
St. George	High in deep soil
Salt Creek (Ramsey)	Med-high
99R	Med-high

Rootstock	Drought Tolerance
1103P	Med-high
Freedom	Med
Schwarzmann	Med
Dogridge	Med
420A	Med

Rootstock	Drought Tolerance
5BB	Med
3309C	Low-med
101-14	Low-med
SO4	Low-med
Harmony	Low-med

Rootstock	Drought Tolerance
St. George	Low-med in shallow soil
O39-16	Low
Riparia Gloire	Low
1616C	Low
5C	Low

Soil Adaptation

- Rootstocks also need to deal with any issues that your soil (or irrigation water) throw at them
  - If you have drainage issues during the growing season you will need “wet feet” tolerance

Rootstock	Wet Feet Tolerance
1616C	High
SO4	Med-high
1103P	Med-high
Schwarzmann	Med
101-14	Med.

Rootstock	Wet Feet Tolerance
110R	Low-med
5C	Low-med
3309C	Low-med
St. George	Low-med
Dogridge	Low-med

Rootstock	Wet Feet Tolerance
420A	Low-med
Salt Creek (Ramsey)	Low-med
140Ru	Low
Riparia Gloire	Low
Harmony	Low

Rootstock	Wet Feet Tolerance
Freedom	Low
5BB	Low
99R	Low
O39-16	--

Soil Adaptation

- Rootstocks also need to deal with any issues that your soil (or irrigation water) throw at them
  - The soil type itself is also important

Rootstock	Soil Type
140Ru	Adapted to drought and acid soils
1103P	Adapted to drought and saline soils
1616C	Best on fertile, med to fine-textured soils
3309C	Deep soils
St. George	Deep soils

Rootstock	Soil Type
Riparia Gloire	Deep, well-drained, fertile, moist soils
420A	Fine-textured fertile soil
110R	Hillside soils, acid soils
99R	Tolerant of acid soil

Soil Adaptation

- Rootstocks also need to deal with any issues that your soil (or irrigation water) throw at them
  - The soil type itself is also important

Rootstock	Soil Type
101-14	Moist, clay soils
5BB	Moist, clay soils
5C	Moist, clay soils
SO4	Moist, clay soils
Schwarzmann	Moist, deep soils

Rootstock	Soil Type
O39-16	Poor on course, sandy soils due to low root knot tolerance
Harmony	Sandy loams and loamy sands
Freedom	Sandy to sandy loams
Salt Creek (Ramsey)	Sandy, infertile
Dogridge	Very sandy, infertile

Other Characteristics

- Some rootstocks have characteristics of special note

Rootstock	Soil Type
110R	Develops slowly in wet soils
140Ru	Does poorly in non-irrigated, low K soils
1616C	Poor on low-vigor sites; tolerates wet soils
3309C	Sensitive to latent viruses; tolerant of cold injury
420A	Scions tend to overbear when young
5BB	Susceptible to phytophthora root rot; adapted to high vigor varieties
99R	Young scions may develop slowly

Other Characteristics

- Some rootstocks have characteristics of special note

Rootstock	Soil Type
Dogridge	Promotes excess vigor, poor fruit set
Freedom	Sensitive to latent viruses
O39-16	Tolerant of fanleaf virus
Riparia Gloire	Early maturation; scions tend to overbear
Salt Creek (Ramsey)	Tolerant to phytophthora
SO4	Noted as a cool-region rootstock
St. George	Fruit set problems with some scions; latent virus tolerant

Rootstock Selection

- That was a ton of information
  - Where did it come from
    - Wine Grape Varieties in California UC ANR Publication 3419 Pages 12-15
      - Table will be pasted on the final slide
  - How do we actually select the proper rootstock

Rootstock Selection

- How do we select the proper rootstock
  - Select rootstock vigor to work with site fertility and production requirements
  - Make sure the rootstock is resistant to local soil pests (nematodes/phylloxera)
  - Remove stocks that aren't adapted to any specific issues in your vineyard
    - EC, Drought, Soil Type
- Hopefully at least one rootstock fits all your needs
  - Or you know what problem you are going to have to fight
    - Don't forget about nutrient uptake
      - Can/should try to fix soil nutrients prior to planting

Rootstock Selection

- Then you call your nursery
  - And take whatever they have available…
  - Nurseries often only have a limited selection of rootstocks available
    - Rootstocks that can generally be used everywhere in California
    - Remember back to pest adaptation
      - The fewer rootstocks we use the more likely pests are to adapt to them

Questions

- Thanks for staying awake
- Thanks again to Bahco for their equipment donations

Rootstock	Influence on Scion		Nematide Resistance		Phylloxera Resistance	Tolerances				Soil Adaptation	Other Characteristics	Vitis Parentage	Ease of Propagation
	Vigor	Mineral Nutrition	Root-knot	Dagger (X. Index)		Drought	Wet Soil	Salinity	Lime				
420A	Low	N,P,K: low Mg: med Zn: low-med	Med	Low	High	Med	Low-med	Low-med	Med-high	Fine-textured fertile soil	Scions tend to overbear when young	berlandieri X riparia	Med
1616C	Low	N: low K: med-high	High	Med	High	Low	High	Med-high	Low-med	Best on fertile, med to fine-textured soils	Poor on low-vigor sites; tolerates wet soils	longii X riparia	High
Riparia Gloire	Low-Med	N,P: Low K,Mg: Low-med	Low	Med	High	Low	Low	Med	Low	Deep, well-drained, fertile, moist soils	Early maturation; scions tend to overbear	riparia	High
SO4	Low-Med	N: low-med P:med K: med-high Mg:med	Med-high	Low-med	High	Low-med	Med-high	Low-med	Med	Moist, clay soils	Noted as a cool-region rootstock	berlandieri X riparia	Med
5C	Low-med	N: low P,K: med Mg: med-high Zn: low-med	Med-high	Low-med	High	Low	Low-med	Med	Med	Moist, clay soils	--	berlandieri X riparia	High
3309C	Low-Med	N: med-high P,Ca: low K,Mg,Zn: med	Low	Low	High	Low-med	Low-med	Low-med	Low-med	Deep soils	Sensitive to latent viruses; tolerant of cold injury	riparia X rupestris	High
5BB	Med	N: med-high P,K,Zn: med Ca,Mg: med-high	Med-high	Med	High	Med	Low	Med	Med-high	Moist, clay soils	Susceptible to phytophthora root rot; adapted to high vigor varieties	berlandieri X riparia	High
110R	Med	N: med P: high K: low-med Mg,Zn: med	Low-med	Low	High	High	Low-med	Med	Med	Hillside soils, acid soils	Develops slowly in wet soils	berlandieri X rupestris	Low-Med
101-14	Med.	N,K: med-high P,Mg,Ca: low Zn: med	Med-high	Med	High	Low-med	Med.	Med.	Low-med	Moist, clay soils	--	riparia X rupestris	High
Schwarzmann	Med	N,P: med K: med-high Mg: low	Med	High	High	Med	Med	Med-high	Med	Moist, deep soils	--	riparia X rupestris	High

Rootstock	Influence on Scion		Nematide Resistance		Phylloxera Resistance	Tolerances				Soil Adaptation	Other Characteristics	Vitis Parentage	Ease of Propagation
	Vigor	Mineral Nutrition	Root-knot	Dagger (X. Index)		Drought	Wet Soil	Salinity	Lime				
99R	Med-high	P: med K: high Mg: med	Med-high	Low-med	High	Med-high	Low	Med	Med	Tolerant of acid soil	Young scions may develop slowly	berlandieri X rupestris	Med
Harmony	Med-high	N: low P: med K: high Zn: low-med	Med-high	Med-high	Low-med	Low-med	Low	Low-med	Med	Sandy loams and loamy sands	--	1613 (solonis X Othello) X Dogridge	High
1103P	Med-high	N: med-high P,Mg: high K,Zn: low-med	Med-high	Low	High	Med-high	Med-high	Med	Med	Adapted to drought and saline soils	--	berlandieri X rupestris	High
St. George	High	N: high P: low on low-P soil, high on high-P soil K: high	Low	Low	High	Low-med in shallow soil; high in deep soil	Low-med	Med-high	Med	Deep soil	Fruit set problems with some scions; latent virus tolerant	rupestris	High
140Ru	High	N: med-high P,Mg: high K: low	Low-med	Low	High	High	Low	Med-high	Med-high	Adapted to drought and acid soils	Does poorly in non-irrigated, low K soils	berlandieri X rupestris	Med
Salt Creek (Ramsey)	High	N,P: high K: med-high Zn,Mn: low	High	Low-med	High	Med-high	Low-med	High	Med	Sandy, infertile	Tolerant to phytophthora	champinii	Low
Freedom	High	N,P,K: high Mg: med Zn,Mn: low	High	High	Low-med	Med	Low	Low-med	Med	Sandy to sandy loams	Sensitive to latent viruses	1613 (solonis X Othello) X Dogridge	Med-High
O39-16	High	N,K: high P: low-med Zn: low	Low	High	High	Low	--	Low-med	Low	Poor on coarse, sandy soils due to low root knot tolerance	Tolerant of fanleaf virus	vinifera X rotundifolia	Very Low
Dogridge	Very high	N,P: high K: med Zn: low	Med-high	Low-med	Med	Med	Low-med	Med-high	Med	Very sandy, infertile	Promotes excess vigor, poor fruit set	champinii	Low