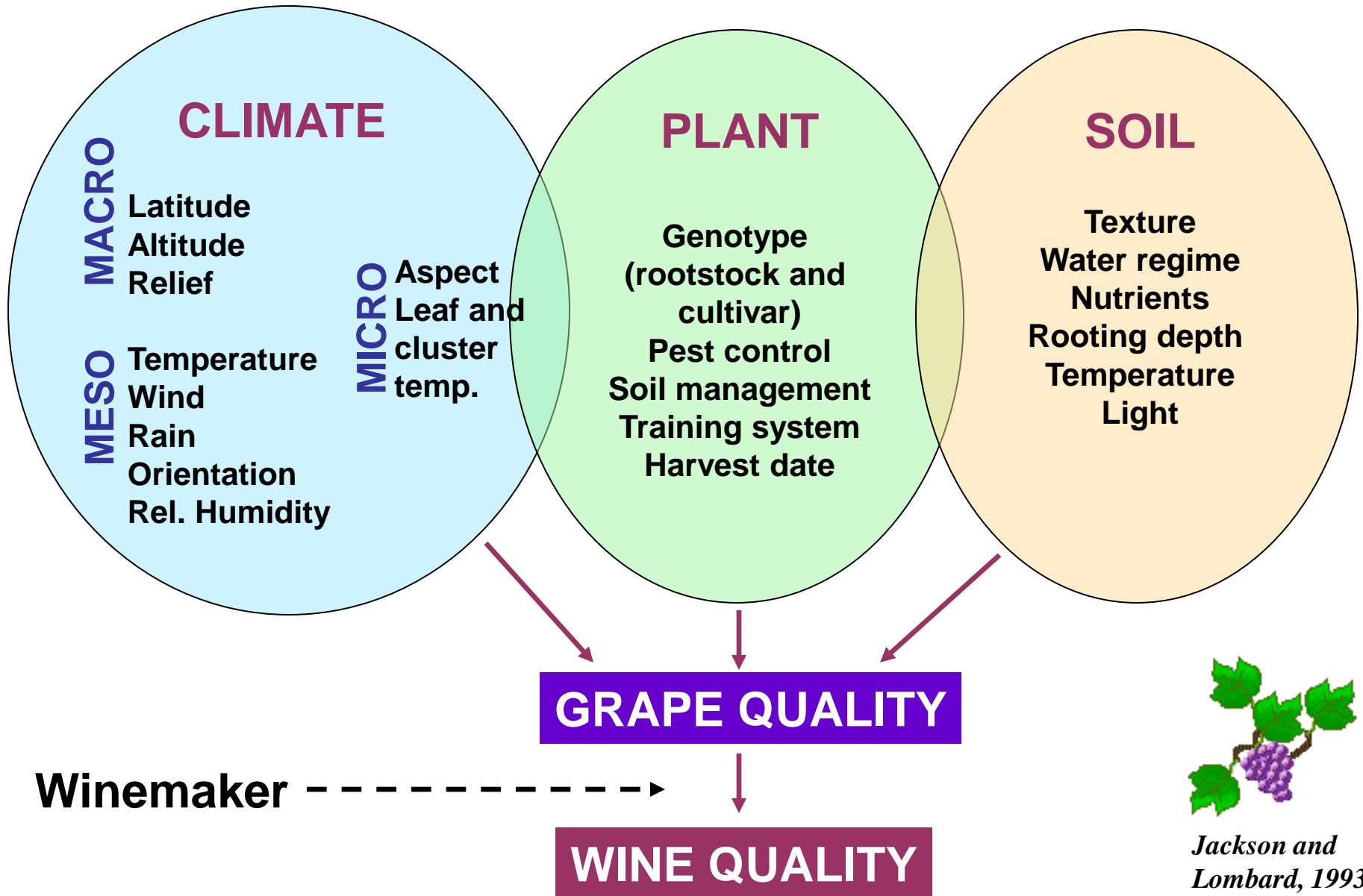


Influence of Soil Factors on Vine Growth and Fruit and Wine Quality

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Viticulture and Enology
UC Davis
January 21, 2011
jjlambert@ucdavis.edu**

Factors Contributing to Wine Quality



Jackson and Lombard, 1993

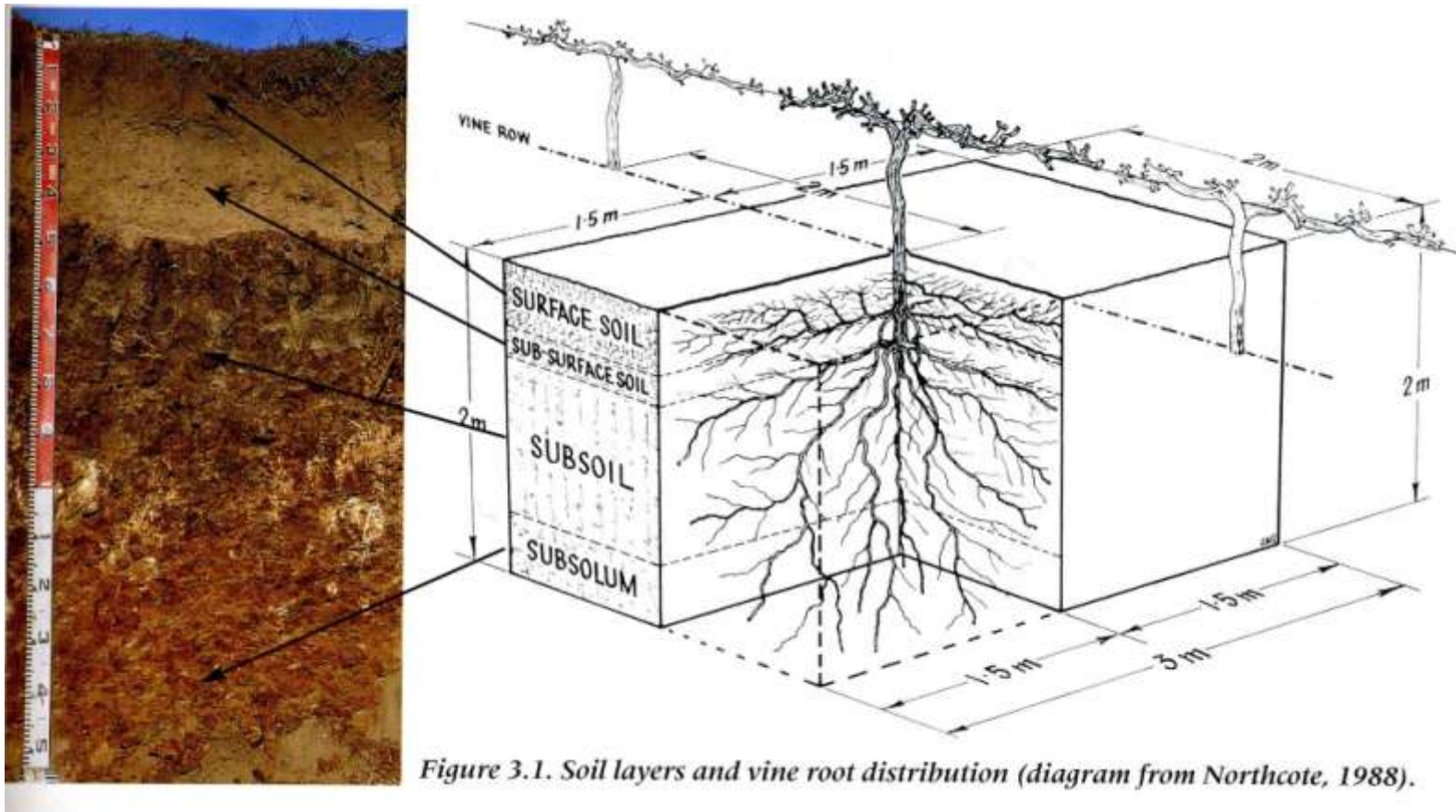
Viticultural Soil Quality

- **Traditionally, vines were grown in the poorest soils (shallow, stony, on slopes) Deep, fertile soils were reserved for food crops.**
- **Increasingly, grapevines have been grown in deeper, more fertile soils after the phylloxera crisis in Europe and in the new wine growing countries.**
- **From earlier times, the belief persists that “poor” soils increase stress on vines, lowering yields but enhancing flavors and aromas.**

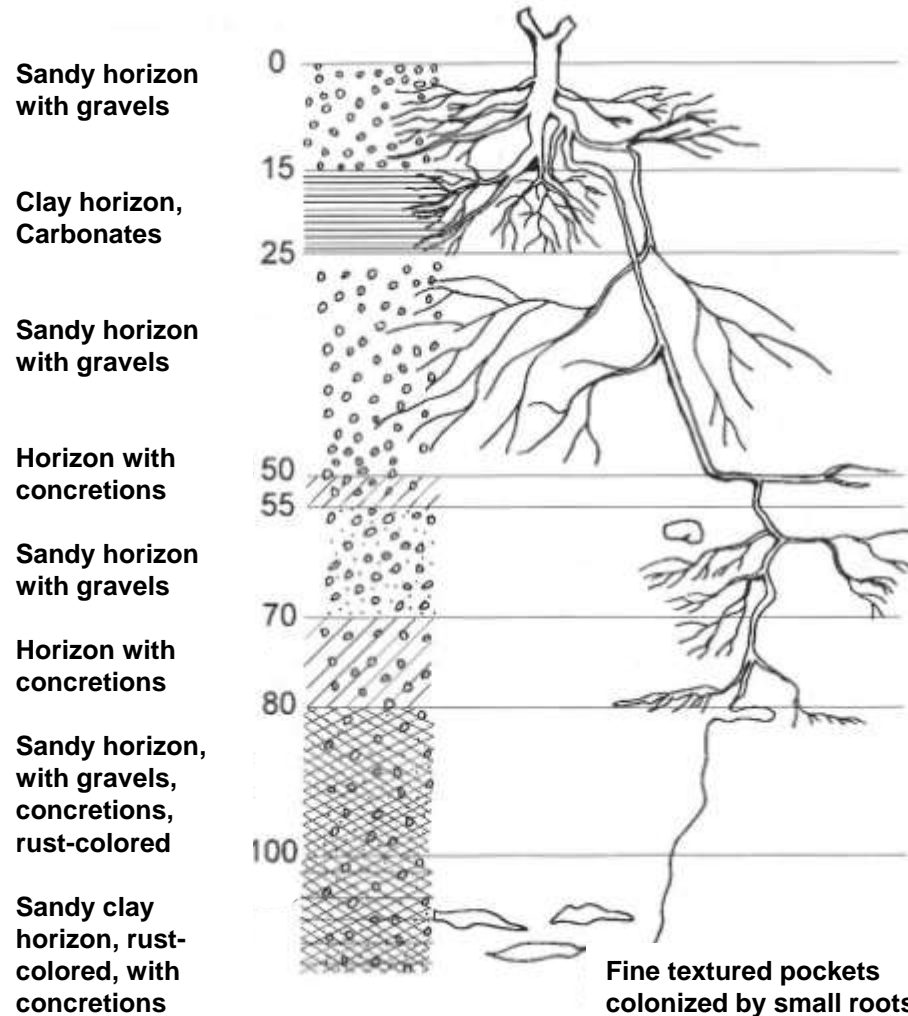
The Soil Factor in Viticulture

- 1) Depth and extent of the root system**
- 2) Soil nutrient content**
- 3) Other soil attributes**
 - a. Depth**
 - b. Coarse fragment content**
 - c. Texture and structure**
 - d. Color**
 - e. pH and Carbonates**
 - f. Limiting subsoil layers**
- 4) Soil temperature**
- 5) Soil water availability**

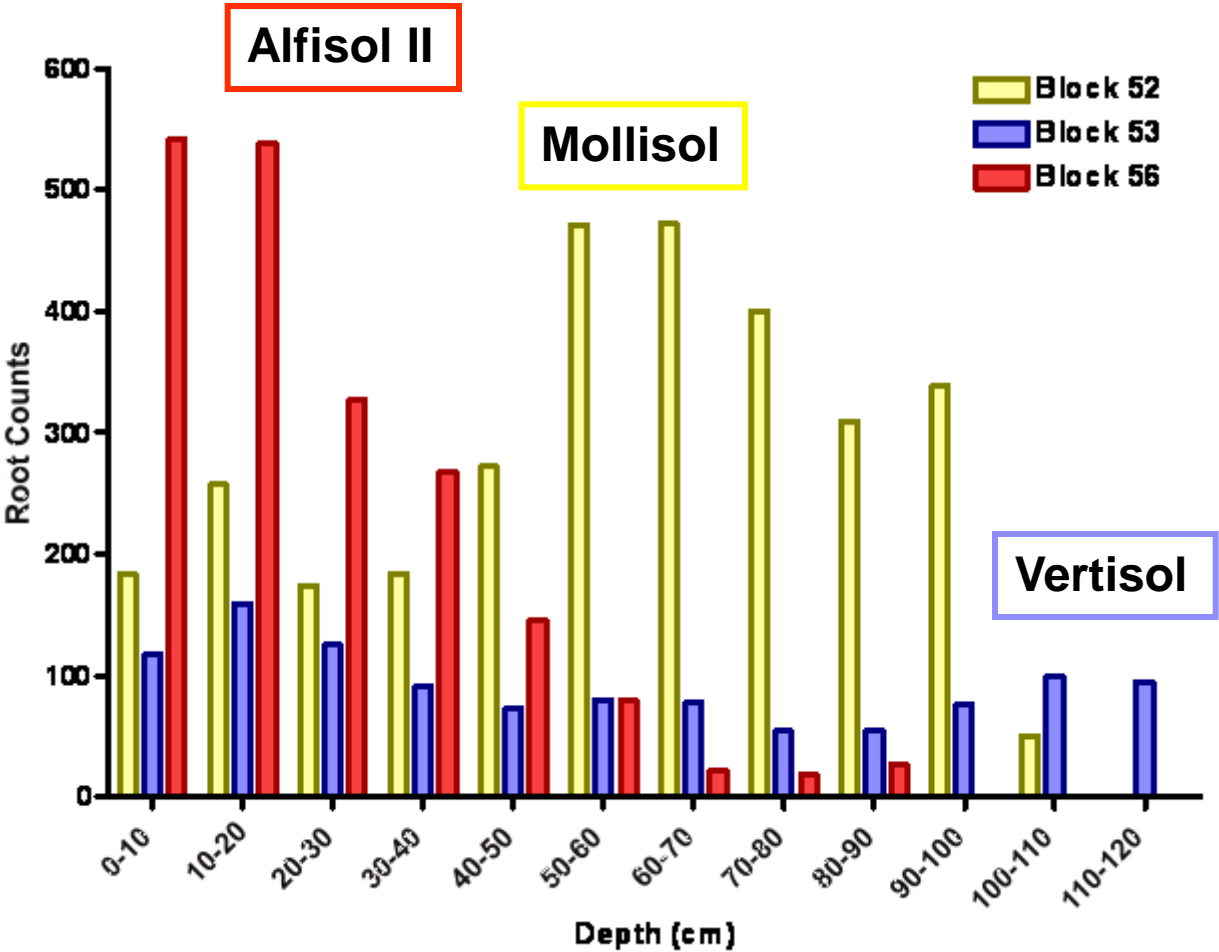
Soil Layers and Vine Root Distribution



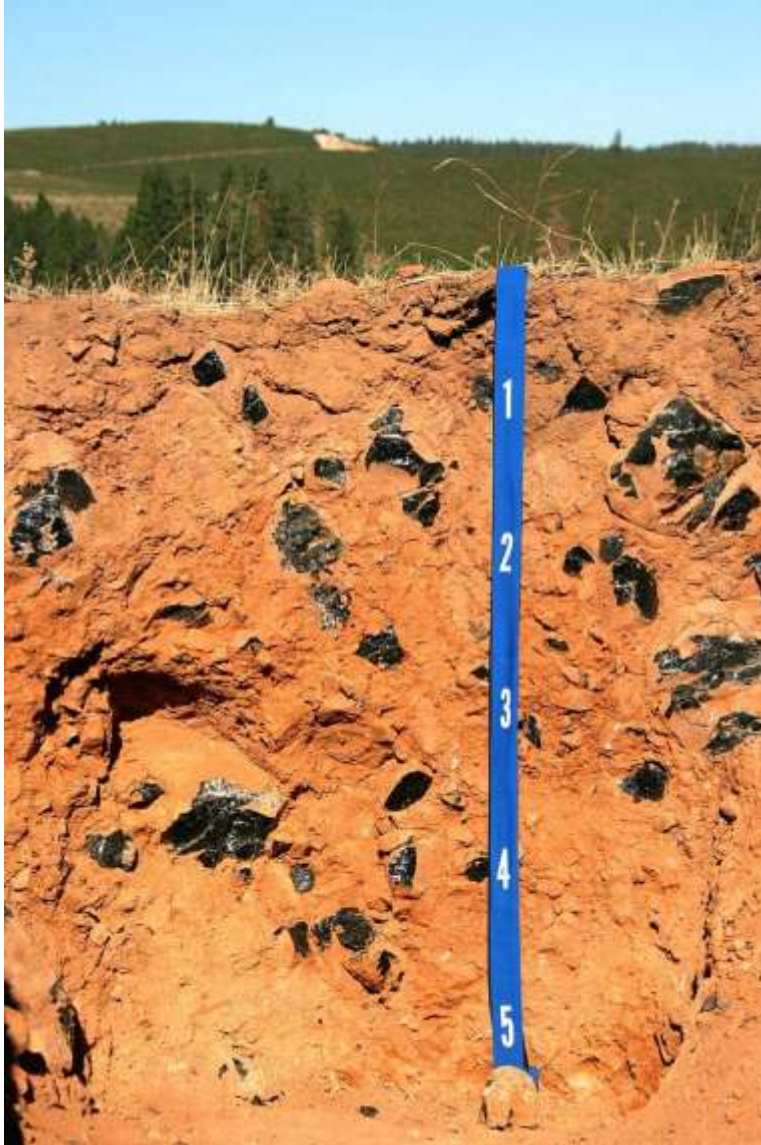
Root Distribution in a Non-Irrigated Vineyard



Root Counts Vary Considerably With Soil Type In an Irrigated Cabernet Sauvignon Vineyard, Paso Robles

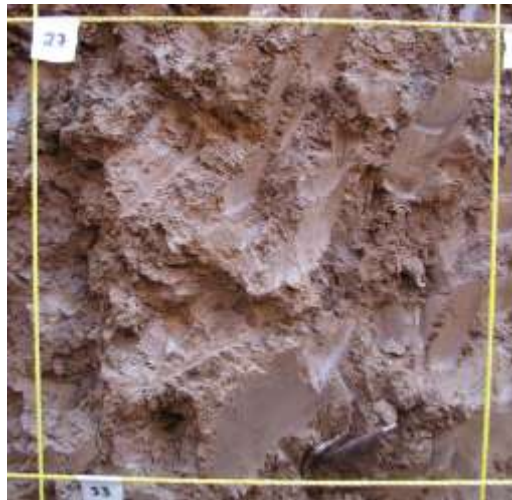


Coarse Fragments in Vineyard Soils

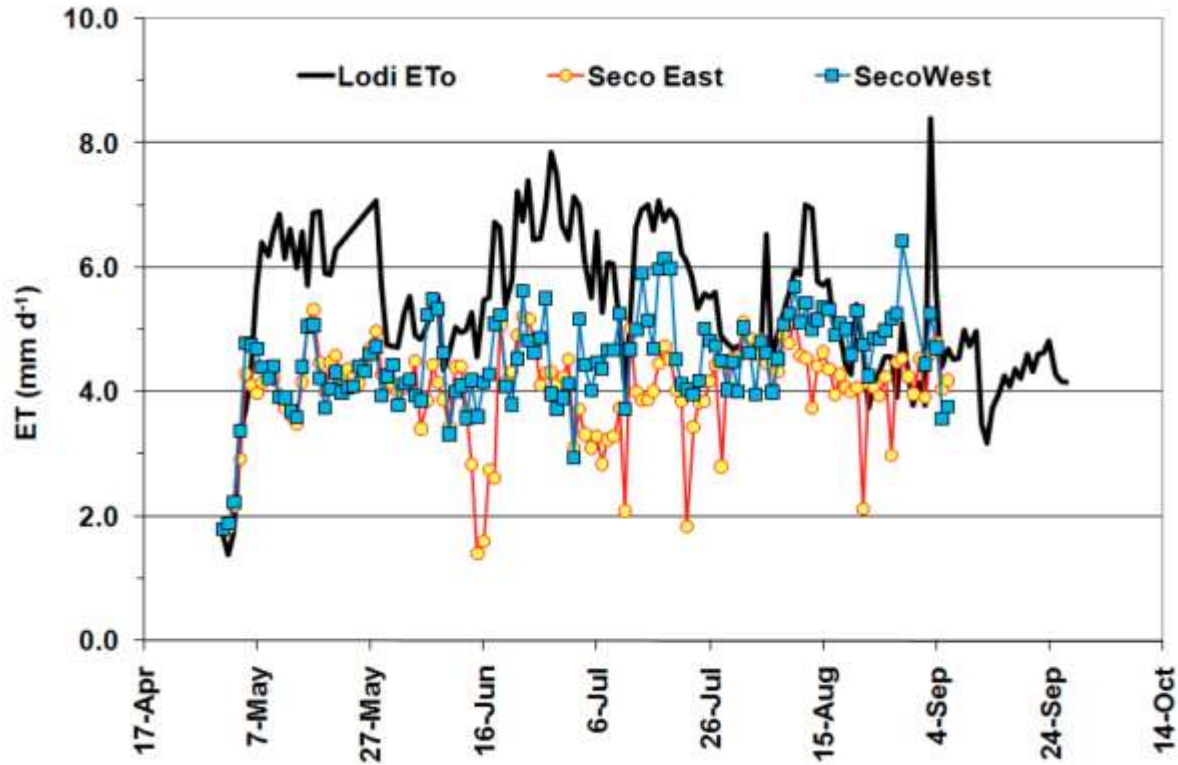


Contrasting Soil Types in a Sacramento County Merlot Vineyard (Rancho Seco)

- Vineyard located on a dissected old alluvial fan of the Laguna formation.
- Two soils were situated on a level terrace and had a strong contrast in gravel content and texture.
- **Western station:** Corning Alfisol with strongly developed argillic horizon, lacking coarse fragments
- **Eastern station:** gravelly to extremely gravelly, weakly developed Alfisol

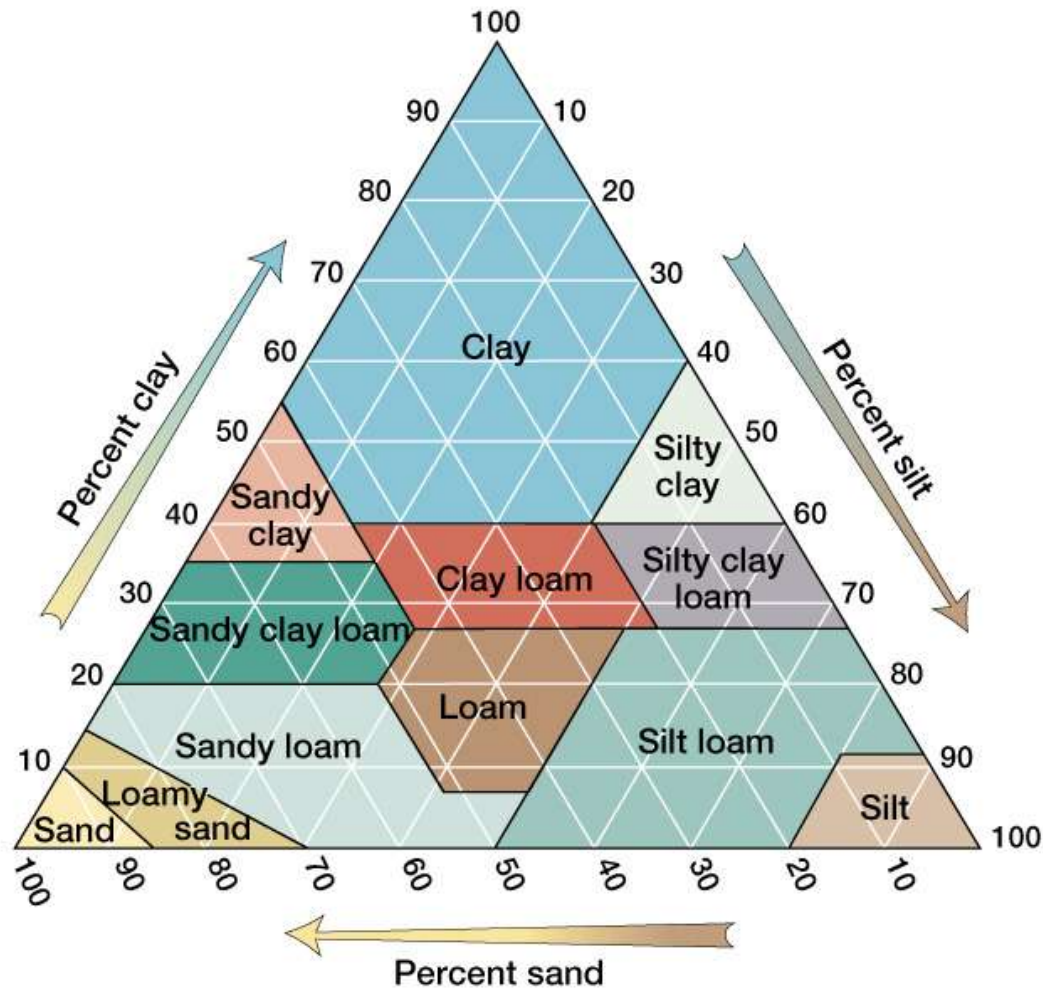


Crop Evapotranspiration on Contrasting Soil Types: Rancho Seco

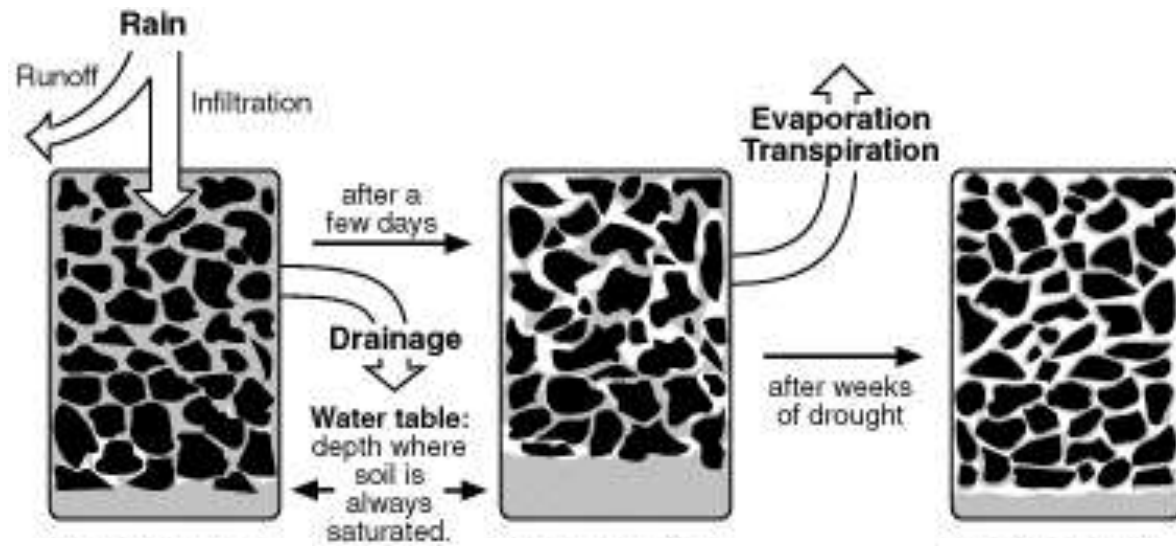


- Rancho Seco: beginning in mid-June, crop ET values on the gravelly soil (**East**) dropped below those on the heavier textured soil (**West**)

Soil Textures: The Texture Triangle



Soil Water Content: Definitions

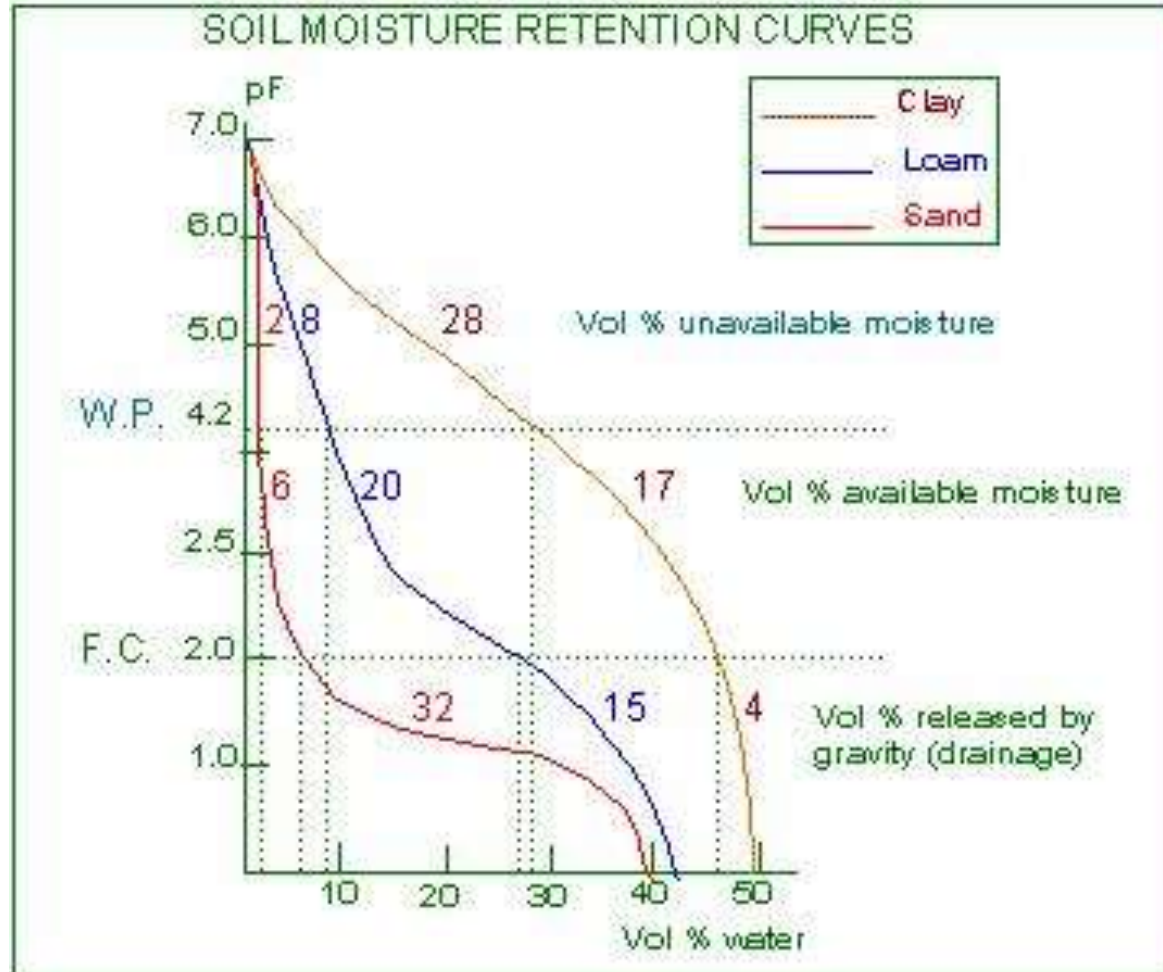


SATURATED SOIL:
All pores are filled.

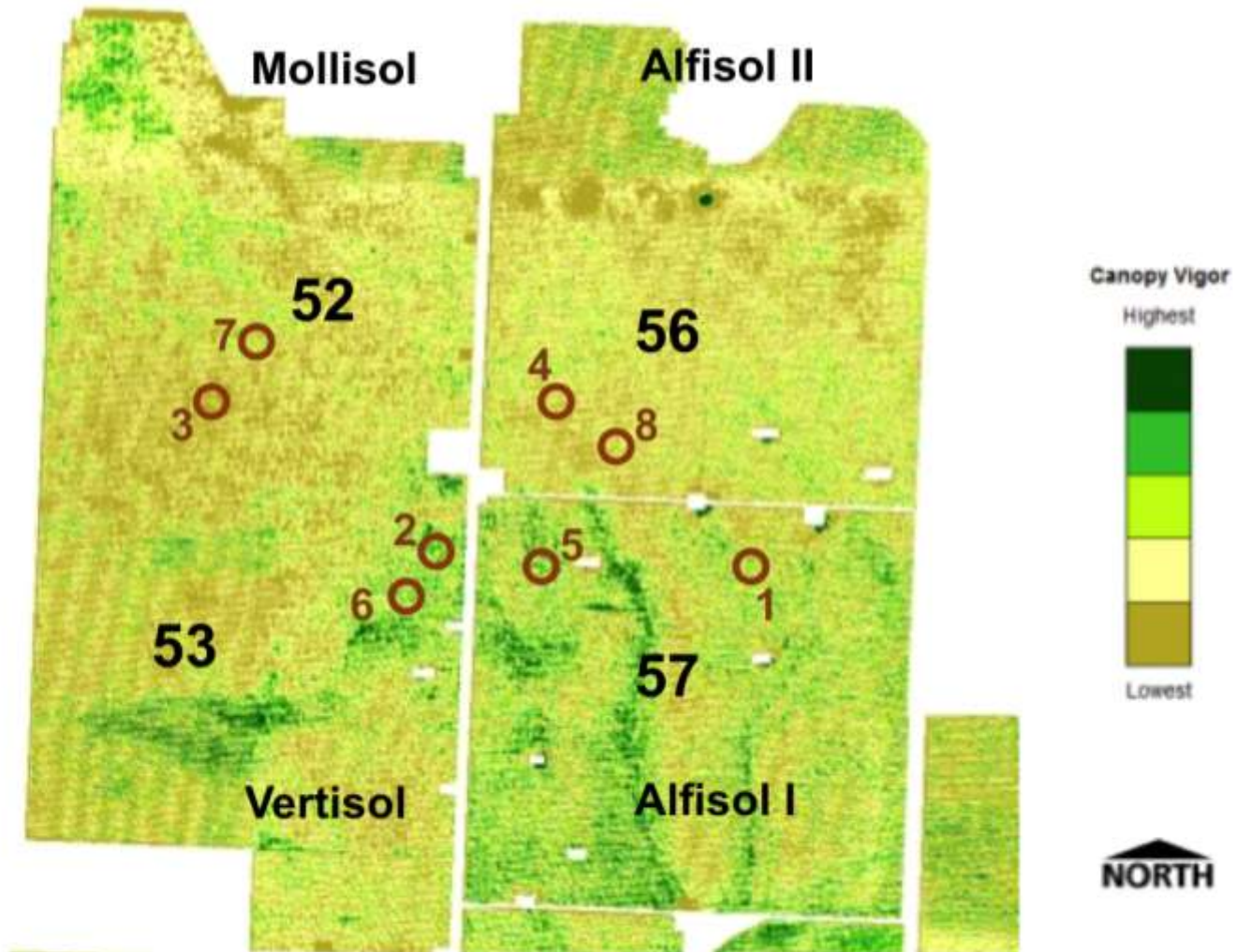
FIELD CAPACITY:
Roughly 50% of
pores are filled.

WILTING POINT:
Plants can't extract
remaining water.

Moisture Retention Varies With Soil Texture

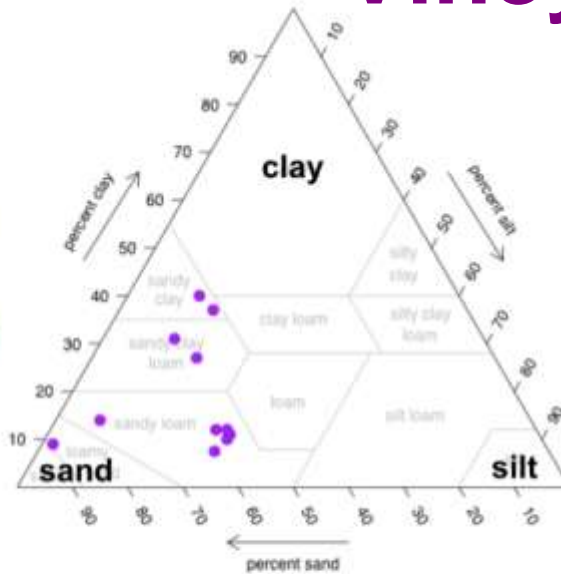


Four Contrasting Soil Types in a Paso Robles Cabernet Vineyard

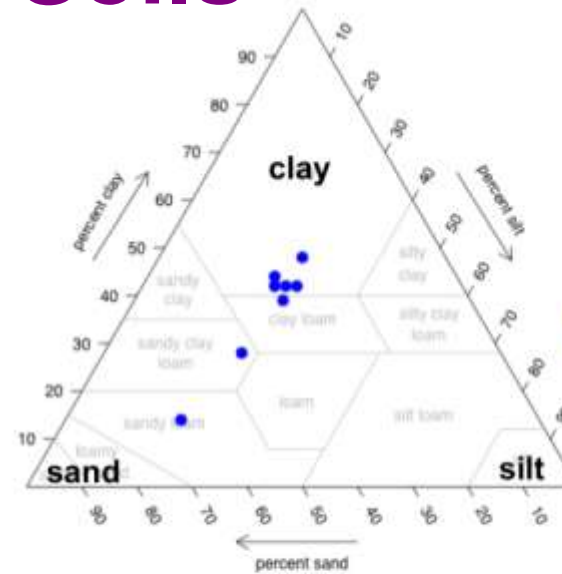


Textural Analysis of Paso Robles Vineyard Soils

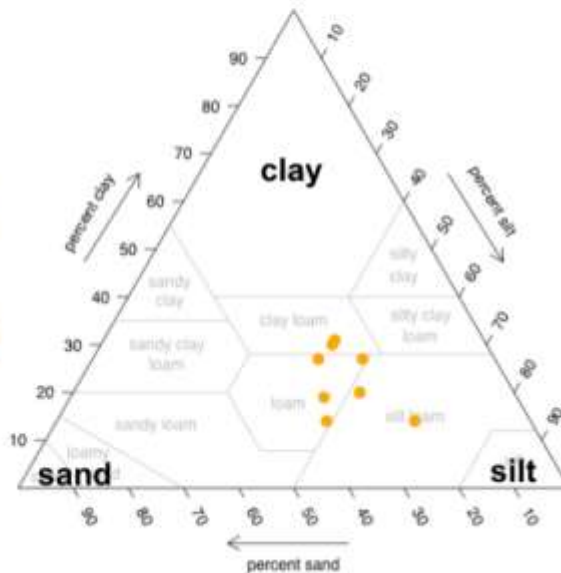
BLOCK 57
(Alfisol I)



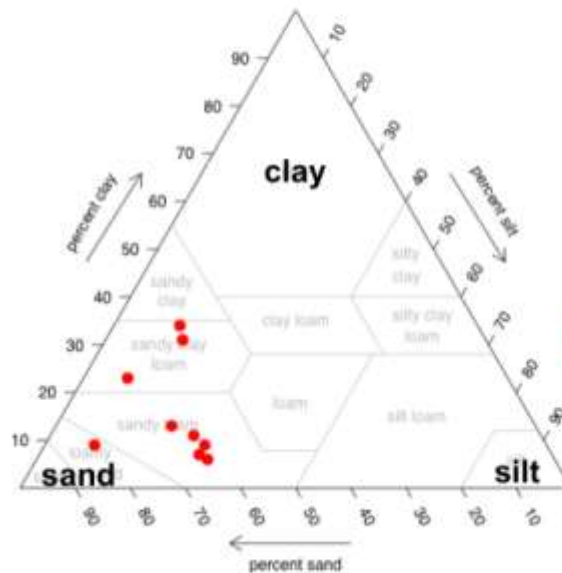
BLOCK 53
(Vertisol)



BLOCK 52
(Mollisol)

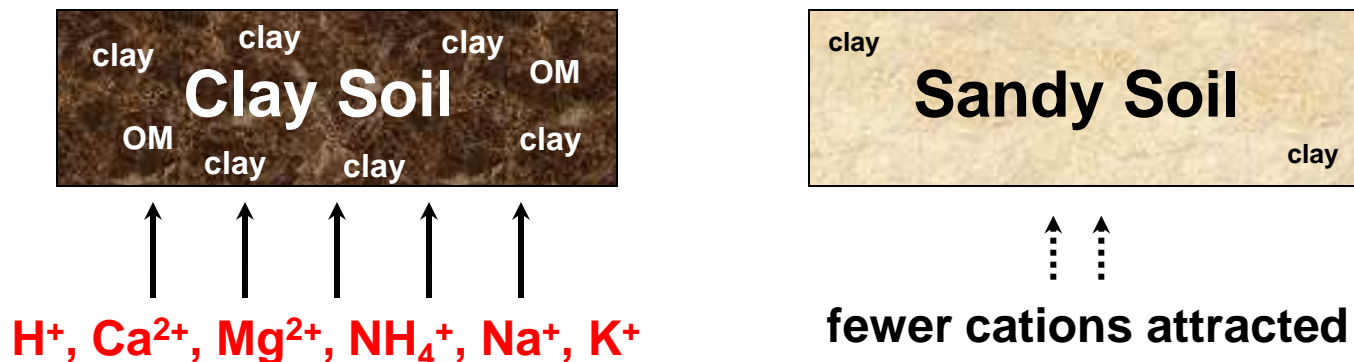


BLOCK 56
(Alfisol II)



Cation Exchange Capacity (CEC)

Cation Exchange Capacity (CEC) is defined as the sum of positive (+) charges of the cations that a soil can adsorb at a specific pH.

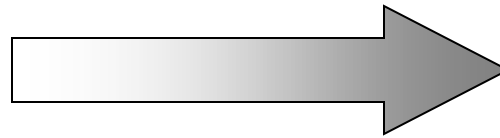


- When clay and OM content are *high*, the overall (-) charge is high, and there are many positions available to capture and exchange (+) ions

Nutrient Behavior in Soils



Sandy soils:
Low organic matter
Large air spaces
Low nutrient status
Free drainage



High-clay soils:
High nutrient capacity
High water-holding capacity
Prone to waterlogging

*As soils increase in clay content,
their cation exchange capacity increases*

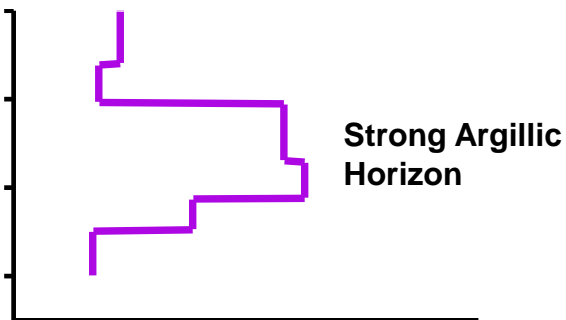
Low CEC and Nutrient Deficiencies

- **Low CEC soils are more likely to develop K and Mg (and other cation) deficiencies**
- **High CEC soils are less susceptible to leaching losses**
- **In sandy soils, a large one-time addition of cations (K) can lead to leaching losses.**
 - **The soil cannot hold onto the excess K.**
 - **More frequent additions of smaller amounts = better.**

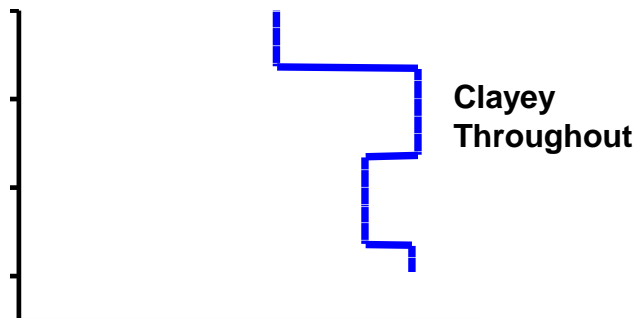
Soil Cation Exchange Capacity

Paso Robles

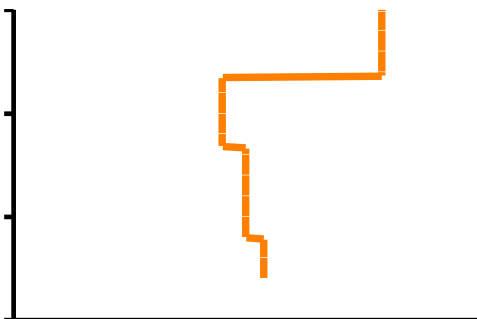
Alfisol I:
Block 57, Pit 5



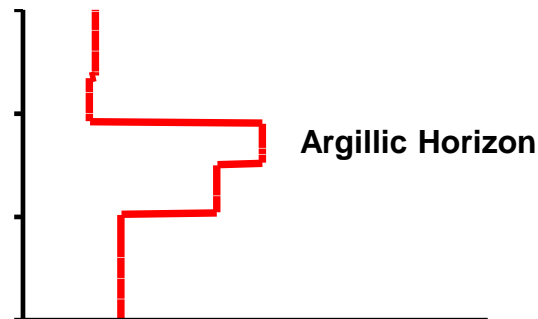
Vertisol:
Block 53, Pit 6



Mollisol:
Block 52, Pit 7



Alfisol II:
Block 56, Pit 8



Depth in cm

K vs Clay Content

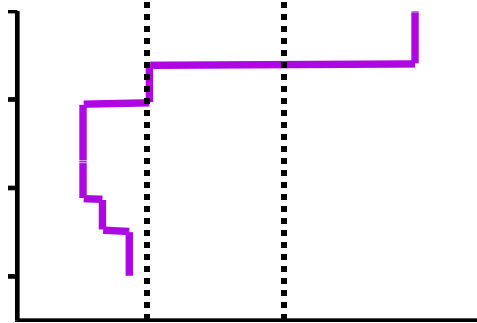
	Exchangeable K (mmol+/Kg soil)			
Clay %	0-10	10-20	20-30	>30
High K	>4.5	>6.4	>7.9	>9.2
Normal K	3.2-4.5	4.9-6.4	6.2-7.9	7.2-9.2
Mediocre K	2.1-3.2	3.8-4.9	4.9-6.2	6.0-7.2
Low K	1.3-2.2	2.6-3.8	3.2-4.9	4.3-6.0
Very low K	<1.3	<2.6	<3.2	<4.3

Source: Crespy, 2007

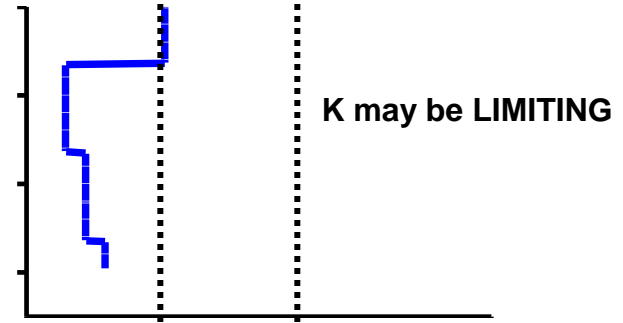
Soil K/CEC Ratio With Depth

Paso Robles

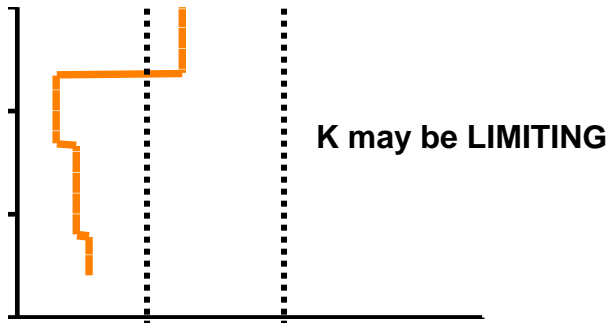
Alfisol I:
Block 57, Pit 5



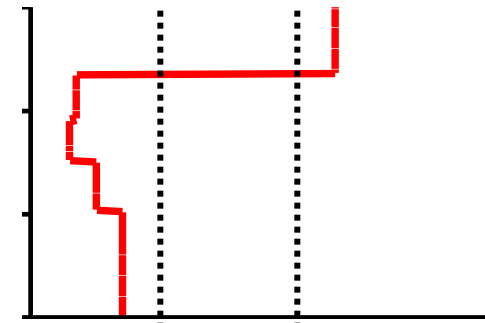
Vertisol:
Block 53, Pit 6



Mollisol:
Block 52, Pit 7



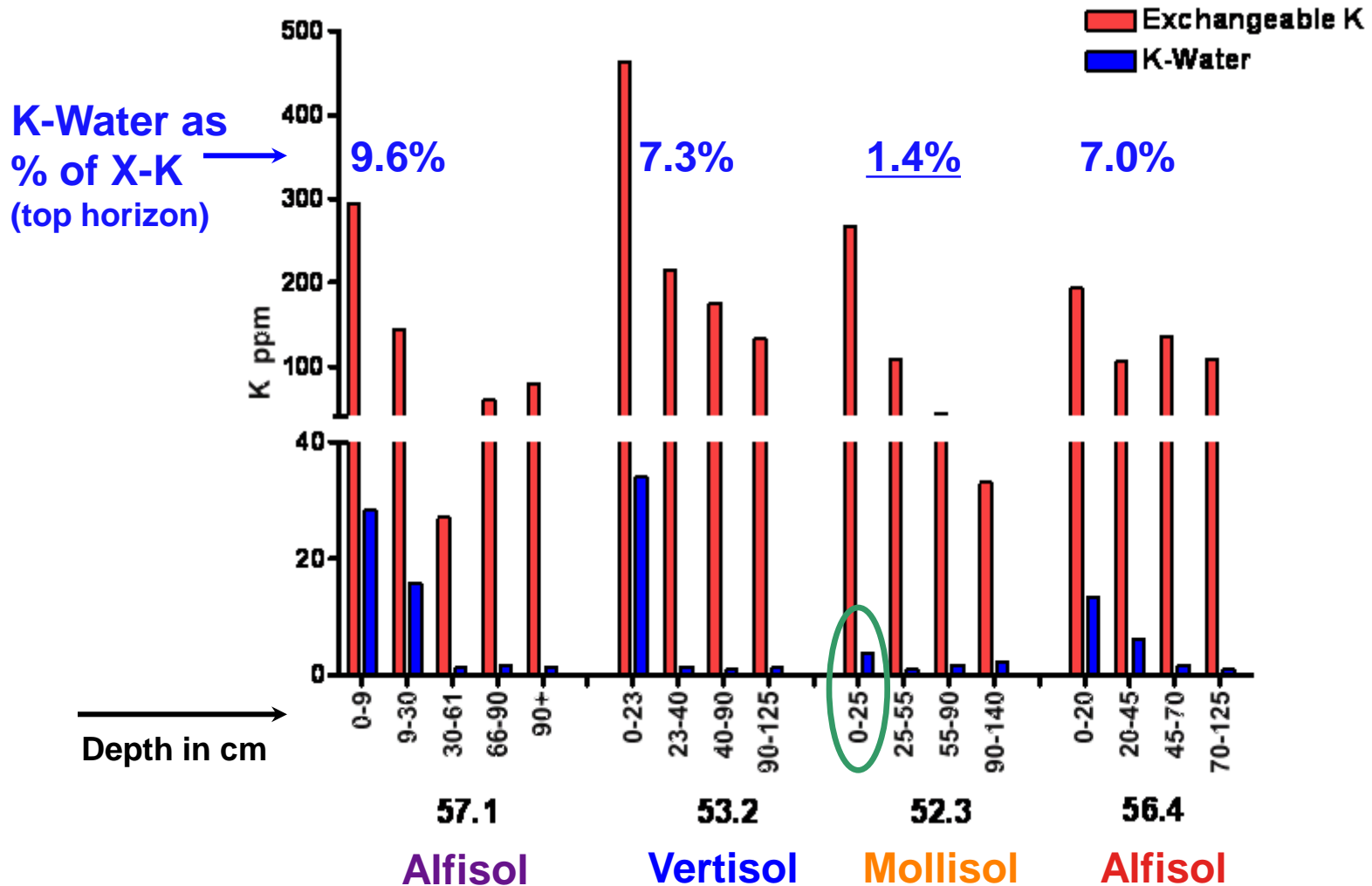
Alfisol II:
Block 56, Pit 8



Depth in cm

Exchangeable vs. Available K

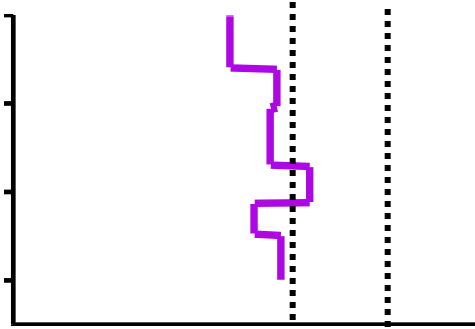
Paso Robles



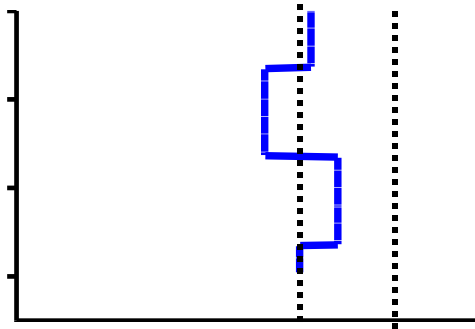
Soil Ca/CEC Ratio

Paso Robles

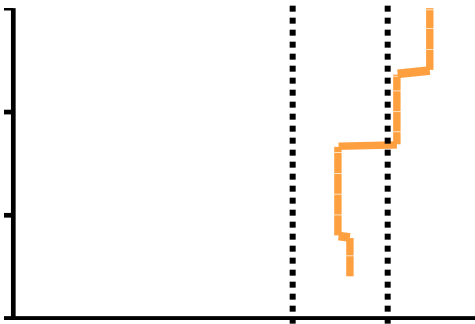
Alfisol I:
Block 57, Pit 5



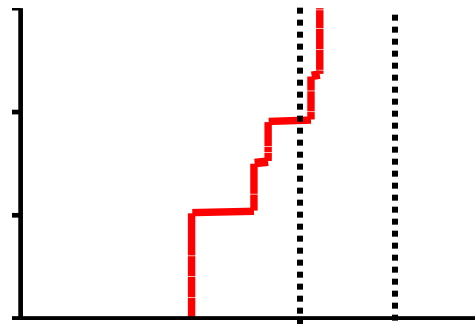
Vertisol:
Block 53, Pit 6



Mollisol:
Block 52, Pit 7



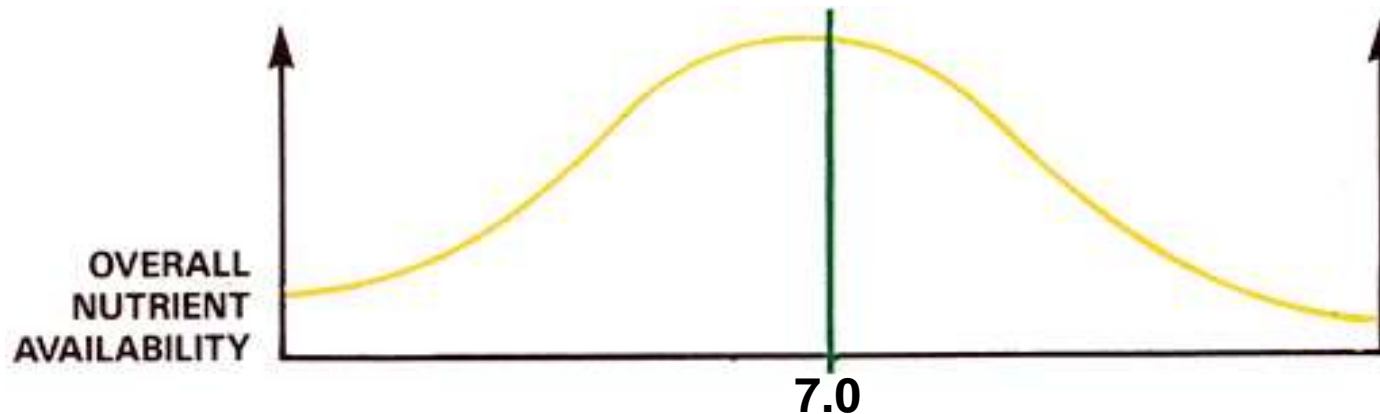
Alfisol II:
Block 56, Pit 8



Depth in cm

High Ca content can limit Fe absorption and bind Phosphate

Soil Nutrient Availability and pH



The availability of most soil nutrients is maximal at or near neutral pH (7.0)

Annual Nutrient Uptake per Vineyard Hectare (by leaves, stems and berries)

Nitrogen (N)	20-70 kg
Phosphorous (P; P₂O₅)	3-10 kg; 7-23 kg
Potassium (K; K₂O)	25-70 kg; 30-84 kg
Magnesium (Mg; MgO)	6-15 kg; 10-25 kg
Calcium (Ca; CaO)	40-80 kg; 56-112 kg
Sulfur (S)	4-8 kg
Iron (Fe)	400-800 g
Boron (B)	80-150 g
Copper (Cu)	60-120 g
Manganese (Mn)	80-160 g
Zinc (Zn)	100-200 g

(1 hectare = 2.5 acres)

Delas, 2000

Average annual uptake of N, P, K

N = 30 kg/ha/yr = 26lbs/ac/yr

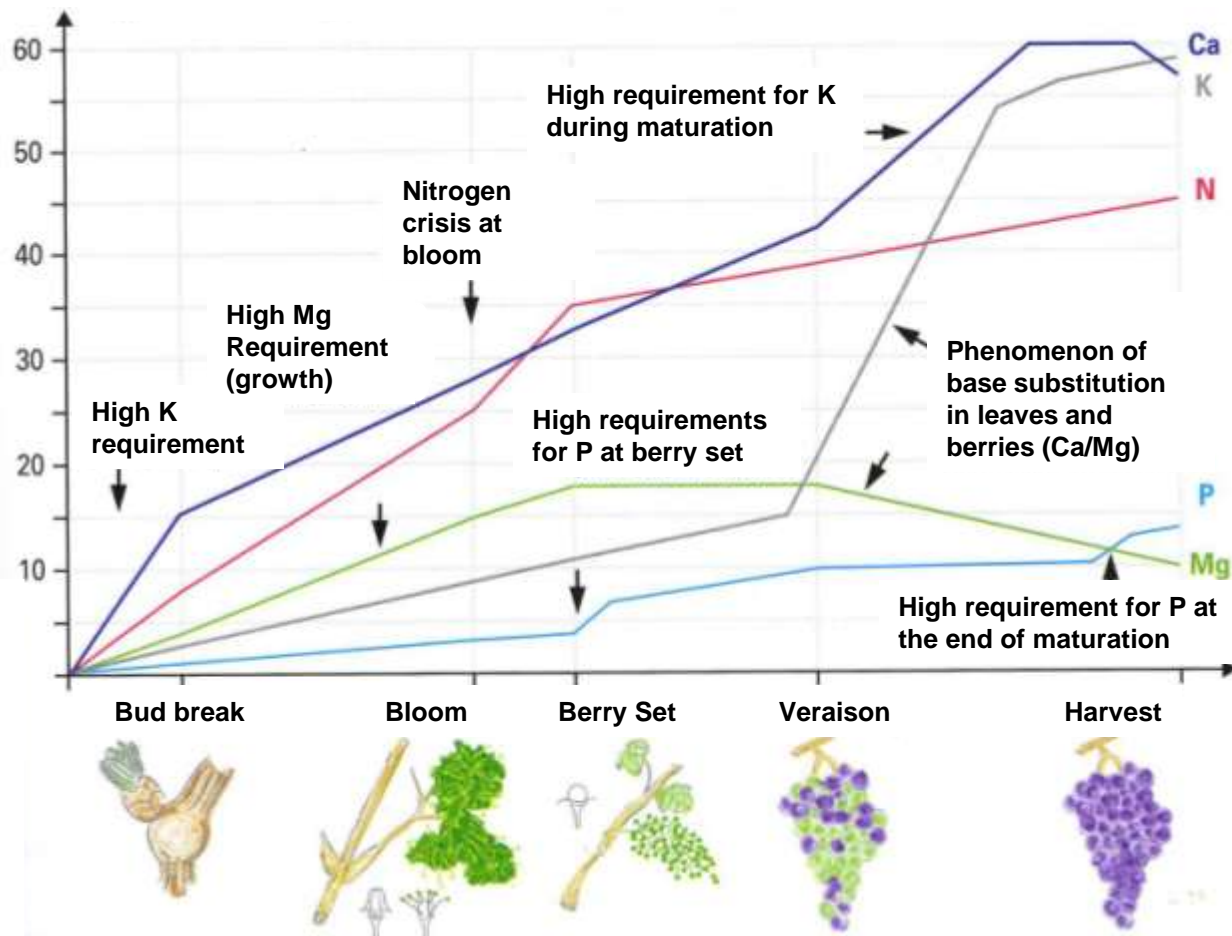
P = 4 kg/ha/yr = 3.6 lbs/ac/yr

K = 25kg/ha/yr = 22 lbs/ac/yr

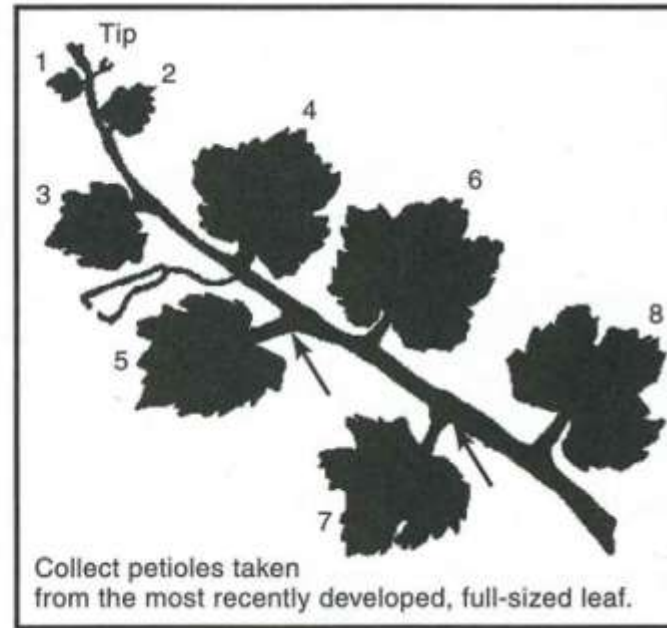
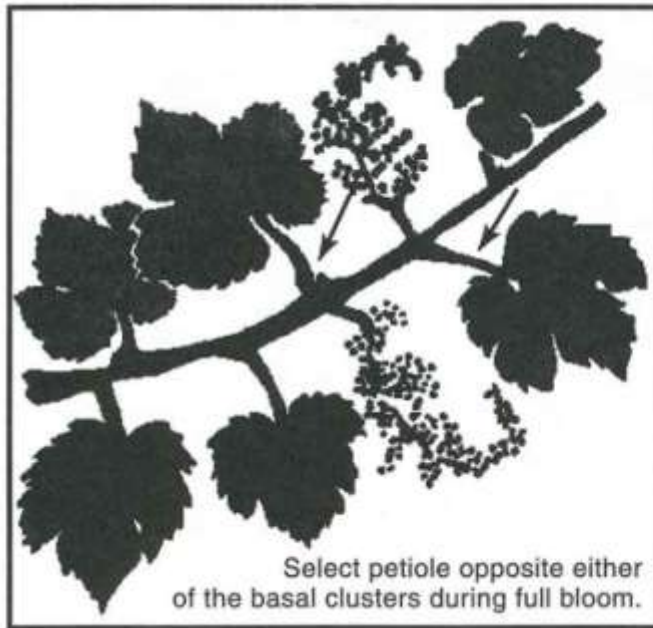
- Leaves fall to the ground and are spread unevenly by wind;
- Prunings are generally reincorporated in the ground;
- Only the grapes are 'removed', and the nutrient content of grapes represents a smaller fraction of the overall nutrient uptake.

Hence, actual nutrient loss from the vineyard is less than the overall uptake by the plant.

Vine Nutritional Requirements During the Growing Season



Leaf Petiole Sampling



- ***Left: Sampling at bloom***
- ***Right: Sampling at veraison***

Interpretation of Petiole Analysis

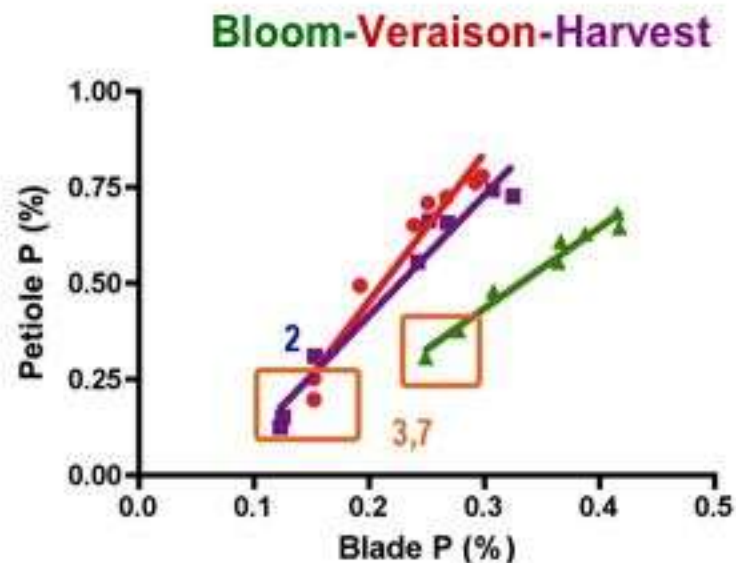
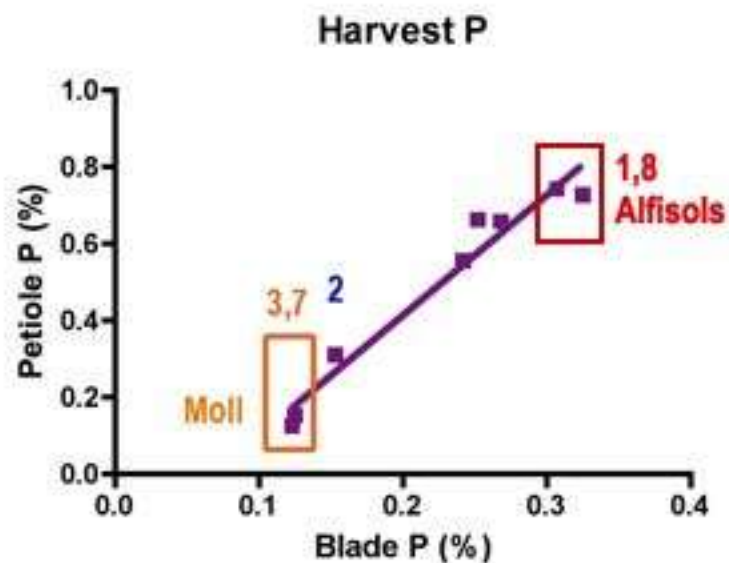
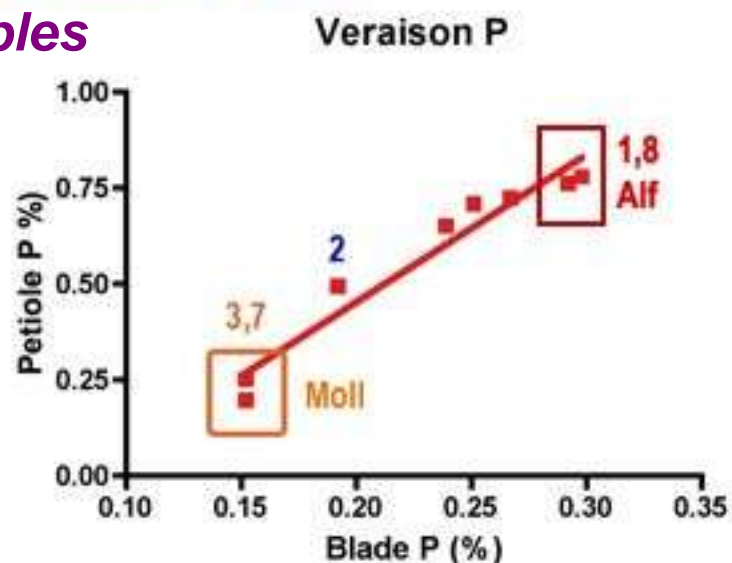
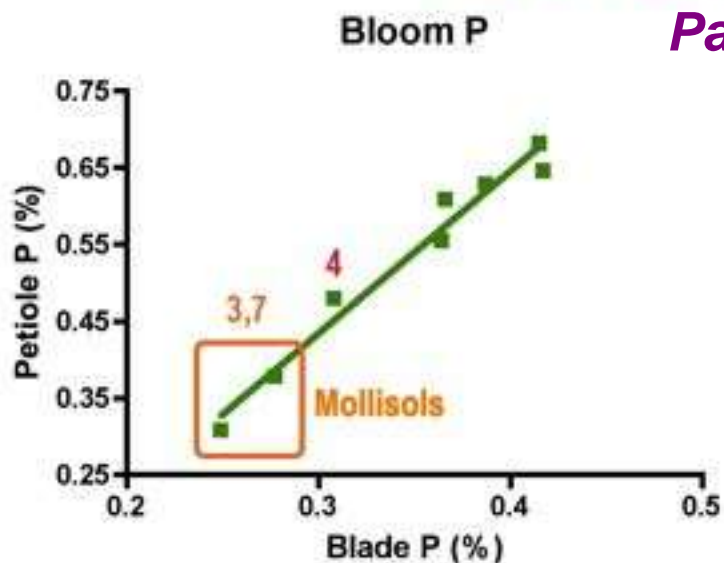
Element	Lower limit*	Upper limit*	Units
N	0.4	0.6	% dry wt
P	0.1	0.18	% dry wt
K	1.0-1.5	2.5	% dry wt
Mg	0.4	0.6	% dry wt
Ca	2	4	% dry wt
Fe	110	160	mg/Kg dry wt
Mn	50	100	mg/Kg dry wt
B	25	40	mg/Kg dry wt
Zn	30	60	mg/Kg dry wt
S	0.2	0.3	% dry wt

***Values below lower limit are considered insufficient; values above upper limit are considered excessive.**

Plant P Levels Vary Significantly By Soil Type

Three-Year Averages 2007-08-09

Paso Robles

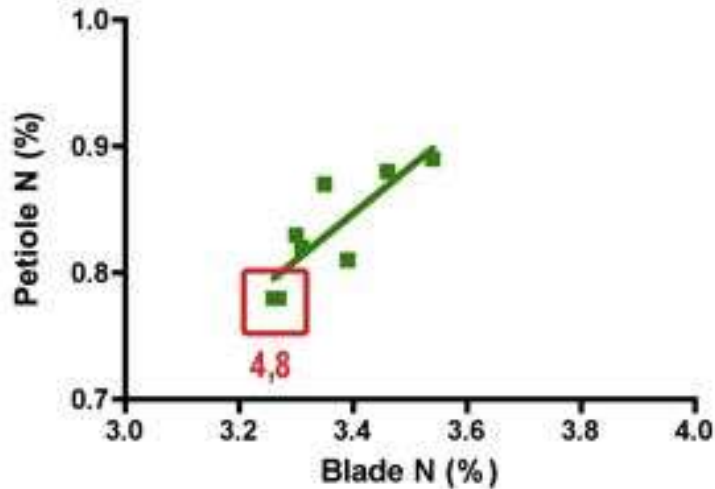


Plant Nitrogen Levels And Soil Type

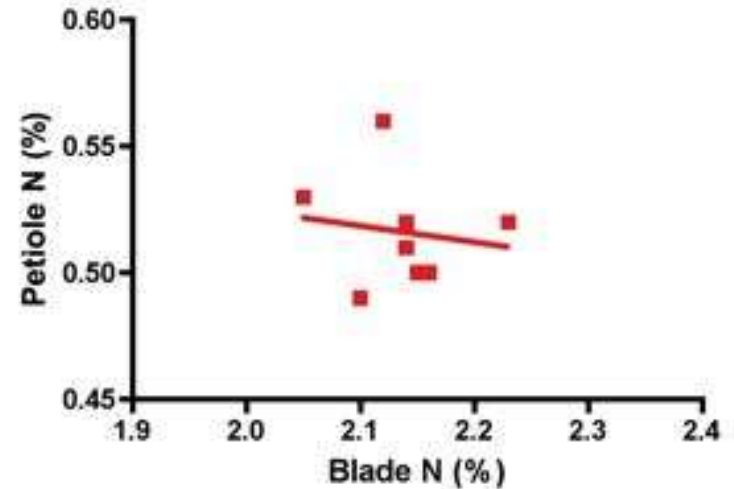
Three-Year Averages

Paso Robles

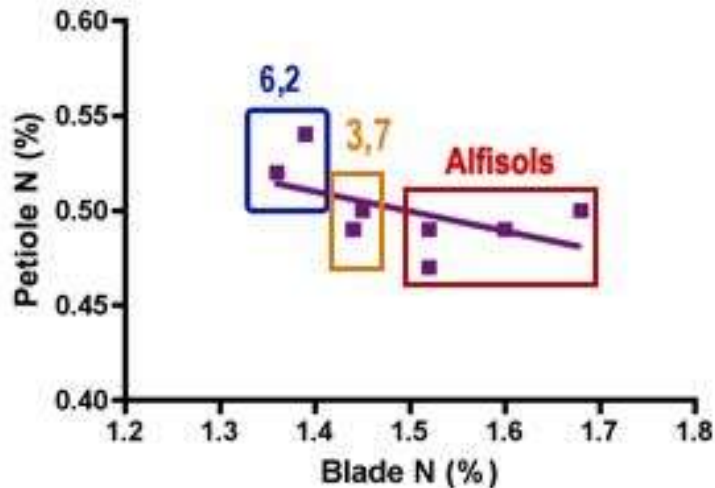
Bloom N



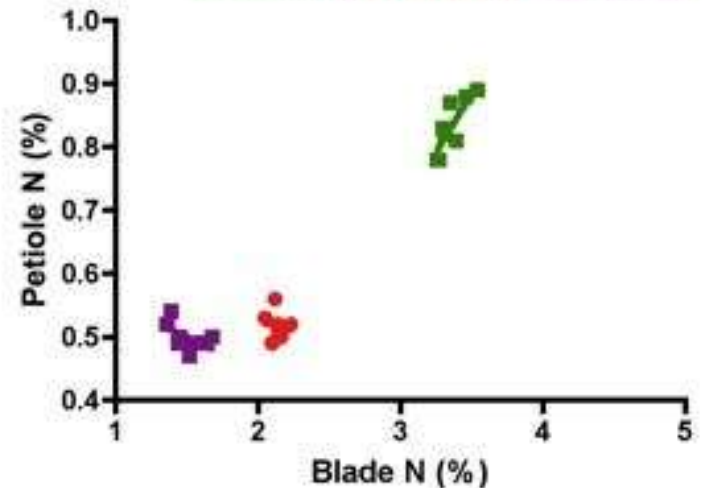
Veraison N



Harvest N



Bloom-Veraison-Harvest

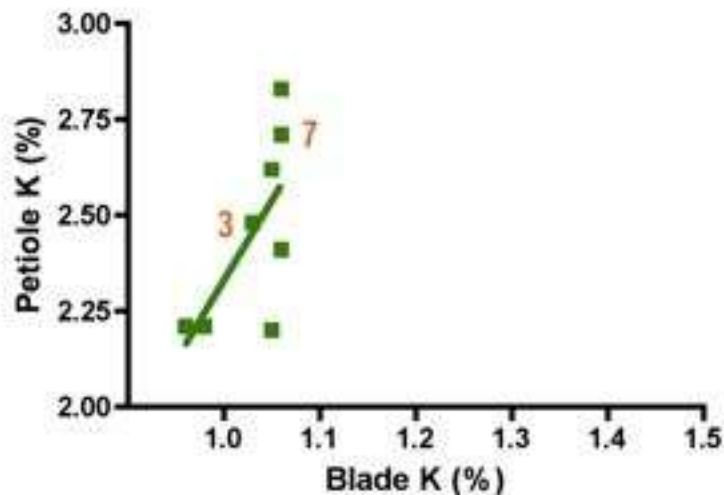


Plant K Shows Clustering By Soil Type

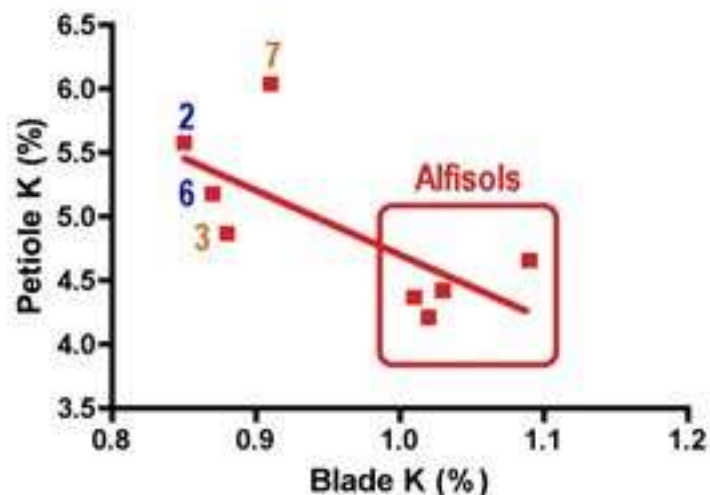
Three-Year Averages

Paso Robles

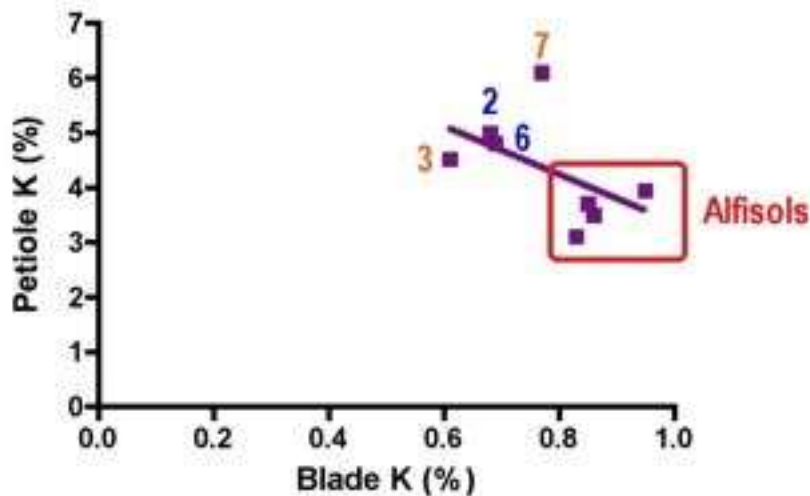
Bloom K



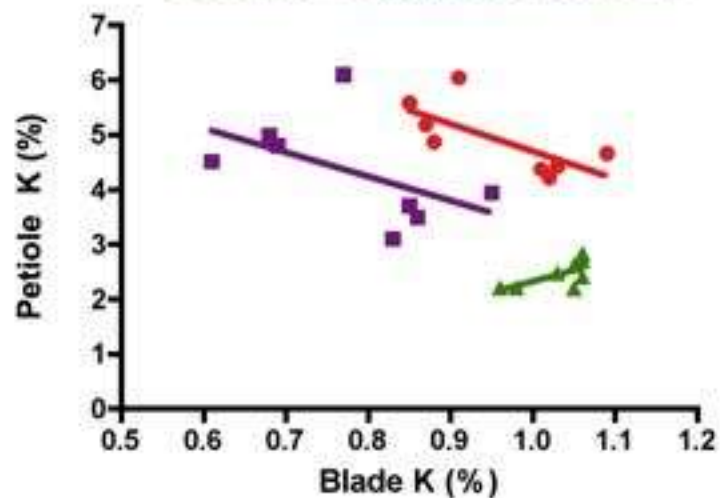
Veraison K



Harvest K



Bloom-Veraison-Harvest



Potassium Uptake By Different Rootstocks

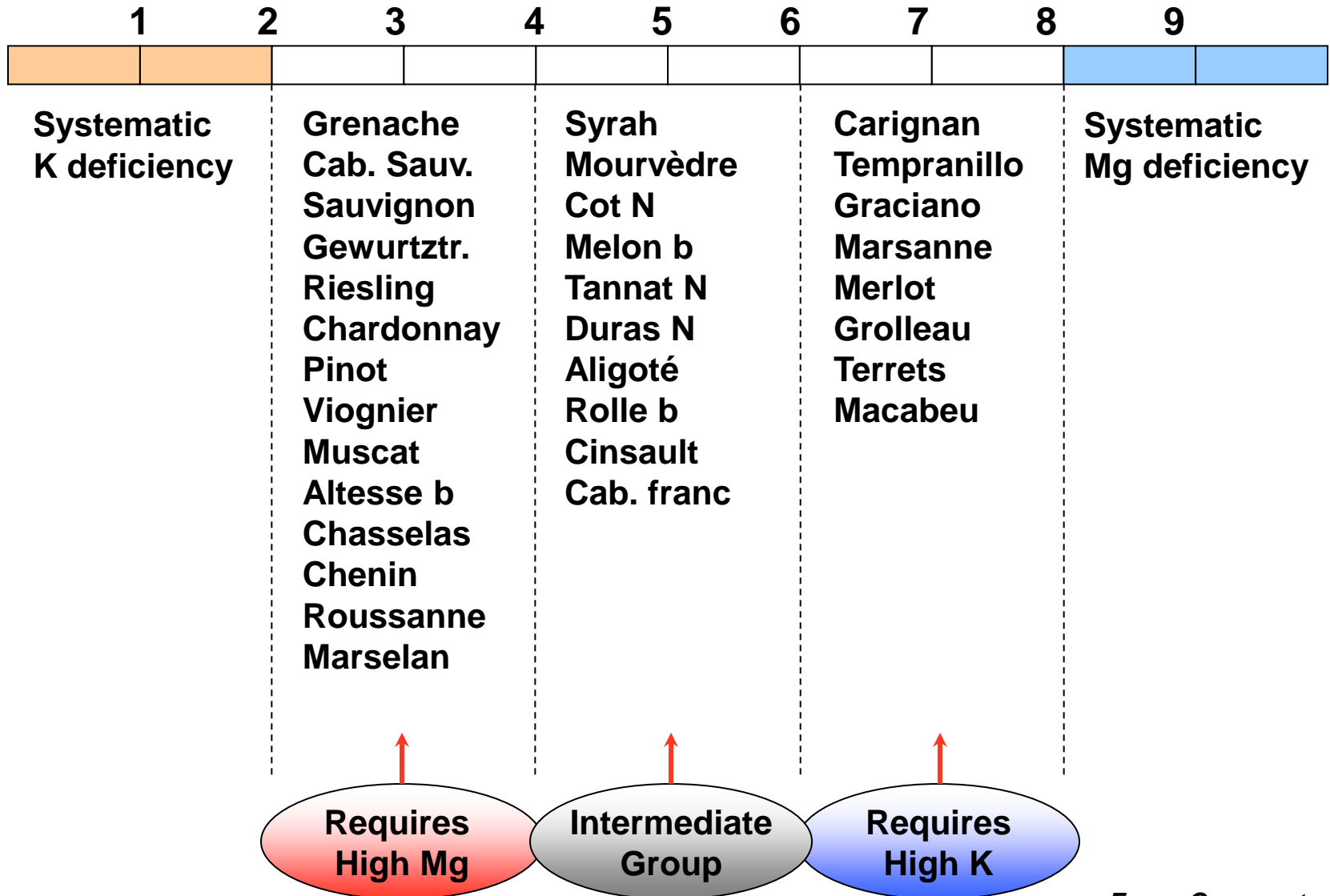
ROOTSTOCK	HIGH UPTAKE	MEDIUM UPTAKE	LOW UPTAKE
Fercal			
44-53			
99R			
110R			
SO4			
1103P			
5BB			
161-49			
Gravesac			
Riparia			
41B			
3309			
420A			
140Ru			
G1			

Rootstock Uptake of K and Mg

	High Uptake of K	High Uptake of Mg
Strong Tendency	44-53 malègue, SO4, Fercal, 5BB, 99R These rootstocks may induce Mg deficiency	1.103P, 140Ru, 41B, 420A, 3.309C, Rupestris du Lot These rootstocks may induce K deficiency
Weak Tendency	110R, 161-49c, 1447P, 196-17cl, 101-14	

K and Mg Requirements

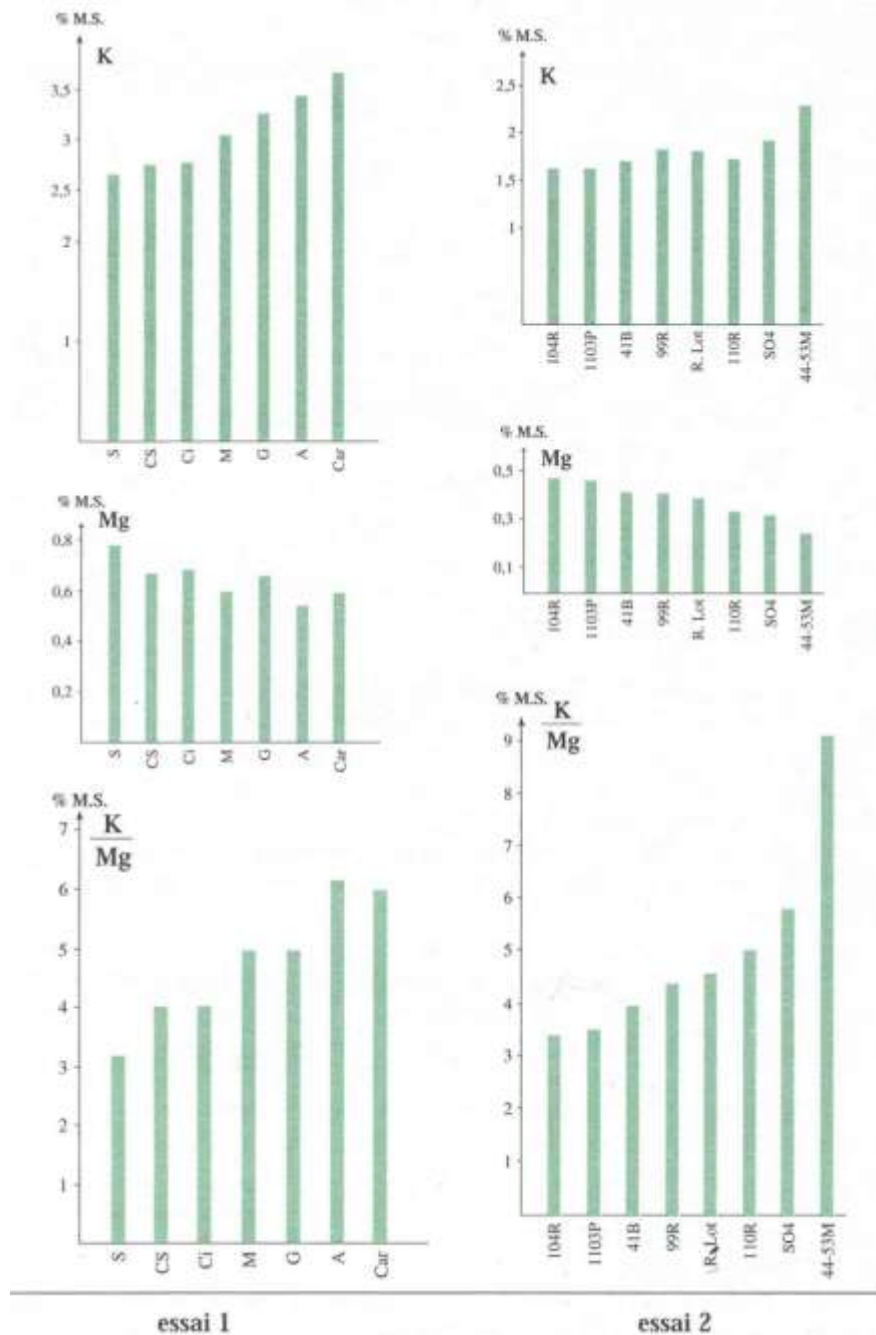
Veraison K/Mg Ratio, Leaves and Petioles



Influence of Rootstock and Varietal on Levels of K and Mg in Leaves

Results of two experiments carried out in Languedoc:

- 1) 7 varieties grafted onto SO4; petioles sampled at bloom and veraison over 4 years
- 2) 8 rootstocks grafted with Grenache; whole leaves analyzed at bloom and veraison over 3 years



Influence of Rootstock on Potassium Levels in Petioles, Must and Wine

Rootstock	Petiole K (% Dry Wt)	Must K (g/L)	Wine K (g/L)	Wine pH
Riparia	2.77	1.69	1.20	3.84
SO4	5.77	2.01	1.53	3.94
Fercal	5.42	2.00	1.67	4.00

- **Graves region, gravelly sand soil, Cabernet Sauvignon vineyard**

Delas, Molot and Soyer, 1990

Influence of K Fertilization on K Content of Petioles, Musts and Wine and on Must and Wine Properties

Fertilization (kg K ₂ O/ha/yr)	Petiole K (% dry wt)	Berry K (% dry wt)	Must K (g/L) ^{1.11}	Must pH	Wine K (g/L)	Wine pH
0 (deficient)	0.40	1.34	1.11	3.06	0.83	3.39
60	2.18	1.89	1.52	3.13	0.94	3.41
120 (excess)	3.57	2.19	1.70	3.19	1.12	3.65

- **Cab. Sauvignon, Riparia rootstock, Medoc region**
(Delas, Molot and Soyer 1990; Delas 2000)
- **Effects of K fertilization on pH of must and wine are very slight, although a pH increase is seen**

Conclusions and Future Directions

- **Soil properties such as texture, water holding capacity, organic matter content, and nutrient levels, influence vine growth and fruit/juice characteristics.**
- **Soil-specific row and plant spacing, combined with proper rootstock-scion combinations, should adjust crop density to the soil carrying capacity.**
- **Site-specific management practices, such as modified irrigation and fertilization systems, can help to mitigate variability and improve fruit uniformity at the vineyard block scale.**

Conclusions and Future Directions

- **The trend towards more sustainable management practices will certainly include the build-up of Soil Organic Matter (SOM) reserves.**
 - **Building soil Organic Matter reserves increases water and nutrient holding capacities, improves soil structure and mineral nutrient availability, increases nitrogen efficiency and porosity, and reduces soil density.**



Acknowledgments



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Rick Snyder

J. Lohr Winery, Paso
Robles

Jerry Lohr
Kim Adams, Steve Carter
Carrie McDonnell, Anji Perry

Bokisch Vineyards,
Rancho Seco

Markus Bokisch

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