SOILS: COMPONENTS AND BASIC CHEMISTRY

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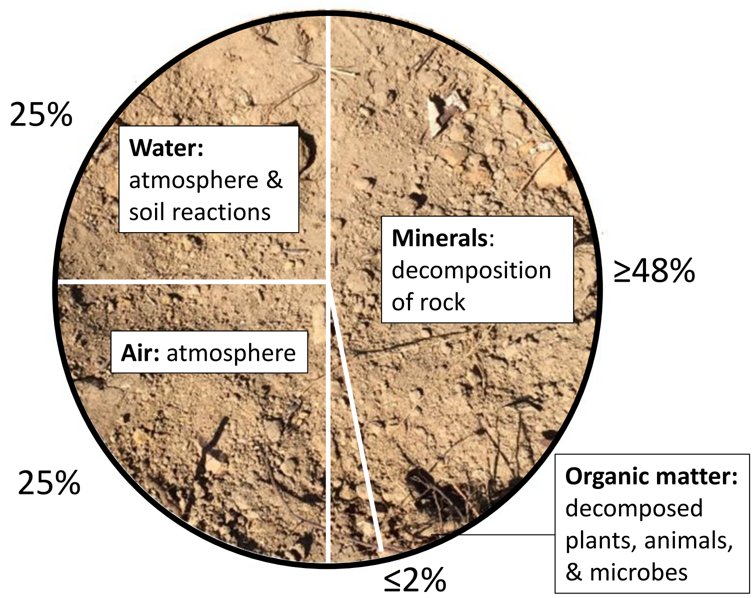
Components of Soil



Soil Formation

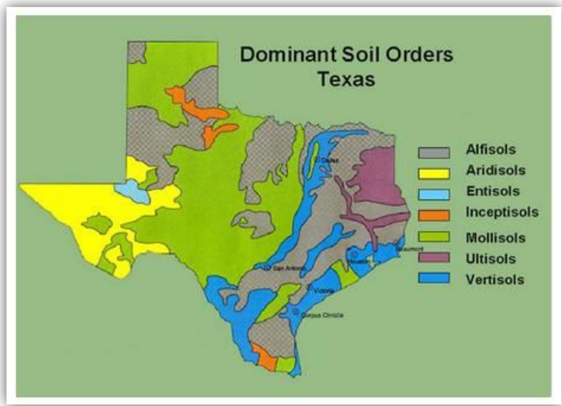
Parent material

Climate

Topography

Time

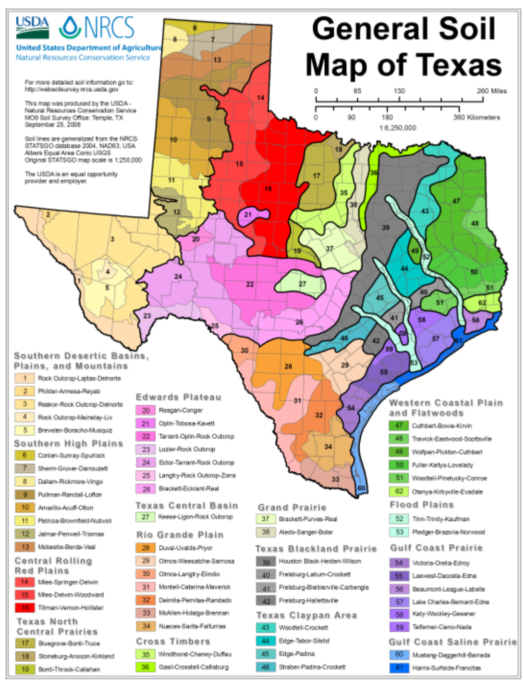
Living organisms



Soil Classification

9 soil orders

>1300 soil series



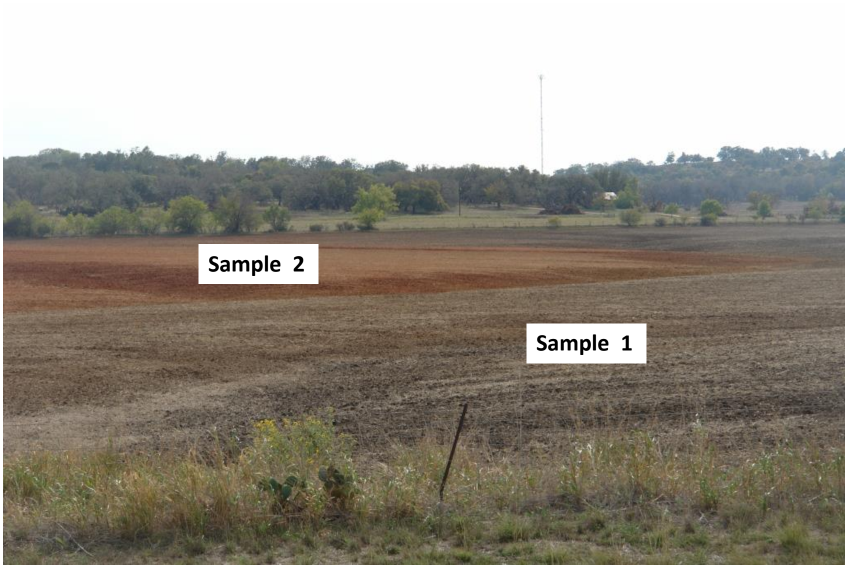


Photo courtesy of Jim Kamas

Soil Profile

Horizons:

A: topsoil (minerals, organic matter)

B: subsoil (clay, low organic matter)

C: parent material

D: rock base

Soil Sampling

Crop Grown: GRAPES

Analysis	Results	CL*	Units
pH	6.7	(5.8)	-
Conductivity	128	(-)	umho/cm
Nitrate-N	1	(-)	ppm**
Phosphorus	31	(50)	ppm
Potassium	46	(150)	ppm
Calcium	869	(180)	ppm
Magnesium	98	(50)	ppm
Sulfur	11	(13)	ppm
Sodium	33	(-)	ppm
Iron	41.11	(4.25)	ppm
Zinc	3.41	(0.27)	ppm
Manganese	13.74	(1.00)	ppm
Copper	0.45	(0.16)	ppm
Boron	0.05	(0.60)	ppm
Limestone Requirement			

0-8” deep

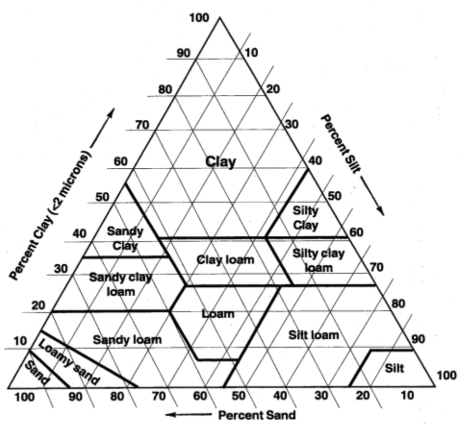
Crop Grown: GRAPES

Analysis	Results	CL*	Units
pH	7.6	(5.8)	-
Conductivity	227	(-)	umho/cm
Nitrate-N	1	(-)	ppm**
Phosphorus	4	(50)	ppm
Potassium	79	(150)	ppm
Calcium	1,505	(180)	ppm
Magnesium	227	(50)	ppm
Sulfur	14	(13)	ppm
Sodium	354	(-)	ppm
Iron	18.66	(4.25)	ppm
Zinc	7.15	(0.27)	ppm
Manganese	3.10	(1.00)	ppm
Copper	0.43	(0.16)	ppm
Boron	1.43	(0.60)	ppm
Limestone Requirement			

8-20” deep

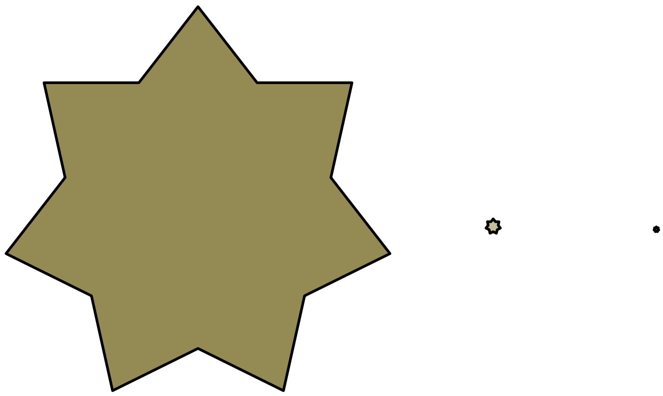
Particle size (Texture)

- Sand: 2-0.05mm
- Silt: 0.05-0.002mm
- Clay: <0.002mm



Texture influences:

- Structure
- Air, & water availability
- Water & nutrient holding capacity

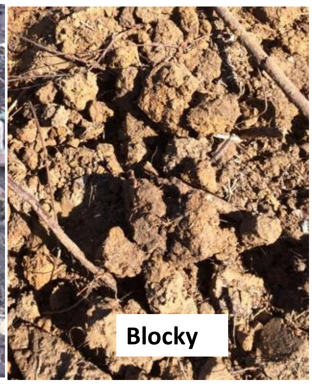


Sand Silt Clay

Loam Clay Loam Clay

Soil Structure

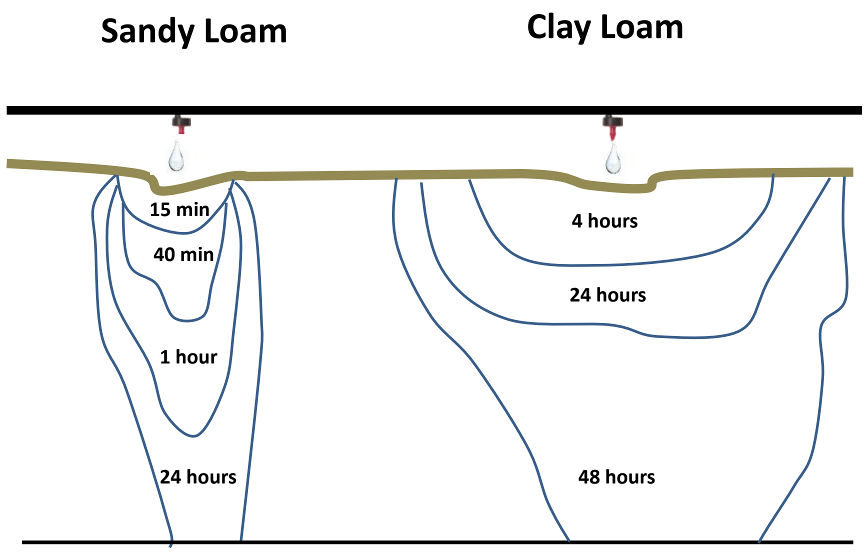
The arrangement of primary particles into naturally formed secondary particles (aggregates) due to the particles tendency to stick together.



Water Holding Capacity

Textural Class	Plant Available Water*
Clay	2.0
Clay Loam	2.4
Loam	2.1
Sandy Loam	1.8
Loamy Sand	1.2
Sand	0.5

*inches of water per foot of soil



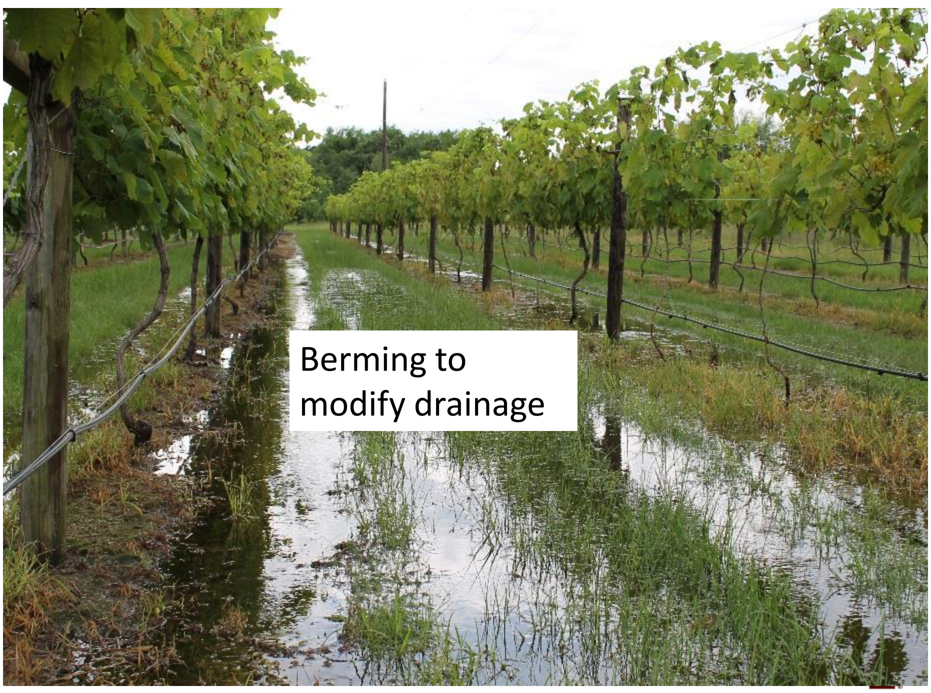
Internal Soil Drainage

Adequate: 1.5” per hour

Excellent: 3” per hour

Signs of Poor Drainage

Image from: http://soil-environment.blogspot.com/



Soil Compaction

Strategies to Improve/Maintain Soil Structure

- Cover cropping
- Organic matter additions

Restrictive Layers

Image from: northamericanfarmer.com

Image from: agric.wa.gov.au

Mineral Nutrition

Macro Nutrients

- Nitrogen
- Phosphorous
- Potassium
- Calcium
- Magnesium
- Sulfur

Micro Nutrients

- Iron
- Copper
- Manganese
- Boron
- Zinc
- Molybdenum

Nutrient	Useable Form(s)	Mobility in Soil
Nitrogen	NH_4^+ (ammonium) and NO_3^- (nitrate)	Slightly mobile, mobile
Phosphorous	$H_2PO_4^-$ (dihydrogen phosphate) and HPO_4^{-2} (hydrogen phosphase)	Immobile
Potassium	K^+	Slightly mobile
Calcium	Ca^{+2}	Slightly mobile
Magnesium	Mg^{+2}	Immobile
Sulfur	SO_4^{-2}(sulfate)	Mobile
Iron	Fe^{+2} (ferrous) and Fe^{+3} (ferric)	Immobile
Manganese	Mn^{+2} and chelates	Mobile
Copper	Cu^{+2}	Immobile
Boron	$H_2BO_3^-$ (boric acid)	Mobile
Zinc	Zn^{+2} and chelates	Mobile

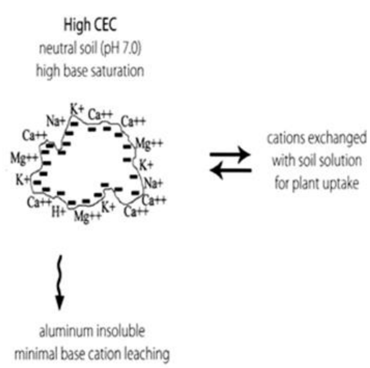
Cation Exchange Capacity (CEC)

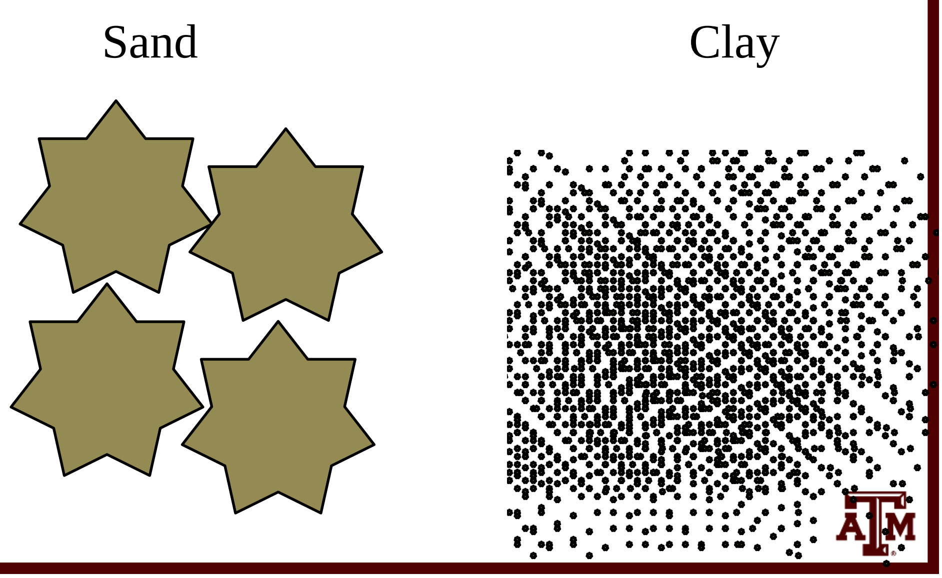
- Soil colloids have a net negative charge

strong attraction weak attraction

$Al^{3+} > Ca^{2+} > Mg^{2+} > K^+ = NH^{4+} > Na^+$

Clay – high CEC
Sand – low CEC
Organic matter – high CEC





Cation Exchange Capacity

Texture	Cation Exchange Capacity (cmol/kg)
Organic matter	40-200
Sand	1-5
Sandy loam	2-15
Silt loam	10-25
clay loam/silty clay loam	15-35
Clay	25-60

Calcium, Potassium, and Magnesium compete for exchange sites

Crop Grown: GRAPES

Analysis	Results	CL*	Units	ExLow VLow Low Mod High VHigh Excess.	Fertilizer Recommended
pH	8.2	(5.8)	-	Mod. Alkaline	
Conductivity	259	(-)	umho/cm	None	
Nitrate-N	3	(-)	ppm**		15 lbs N/acre
Phosphorus	7	(50)	ppm		25 lbs P2O5/acre
Potassium	175	(150)	ppm		0 lbs K20/acre
Calcium	28,454	(180)	ppm		0 lbs Ca/acre
Magnesium	50	(50)	ppm		5 lbs Mg/acre
Sulfur	12	(13)	ppm		5 lbs S/acre
Sodium	30	(-)	ppm		
Iron					
Zinc					
Manganese					
Copper					
Boron					
Limestone Requirement					0.00 tons 100ECCE/acre

Nutrients Removed with Harvest

Nutrient	Pounds removed per ton of fruit	Pounds removed per 5 ton crop
Nitrogen	6.6	33
Phosphorous	0.88	4.4
Potassium	8.8	44
Calcium	2.2	6
Magnesium	0.44	2.2

From: M. Keller, Science of Grapevines

Target Values for Vineyard Soil Nutrients

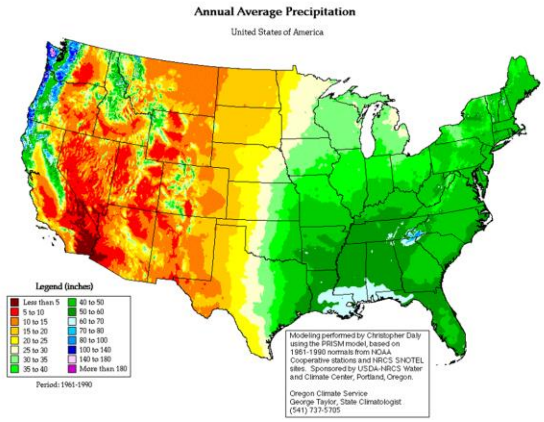
Nutrient	Target soil values (ppm)	Target soil values (lbs/acre)
Potassium (K)	75-100	150-200
Phosphorus (P)	20-50	40-100
Calcium (Ca)	500-2,000	1,000-4,000
Magnesium (Mg)	100-250	200-500
Boron (B)	0.3-2	0.6-4
Iron (Fe)	20	40
Manganese (Mn)	20	40
Copper (Cu)	0.5	1.0
Zinc (Zn)	2	4
Organic Matter	3-5%	-

From: T. Wolf, Winegrape Production Guide for Eastern North America

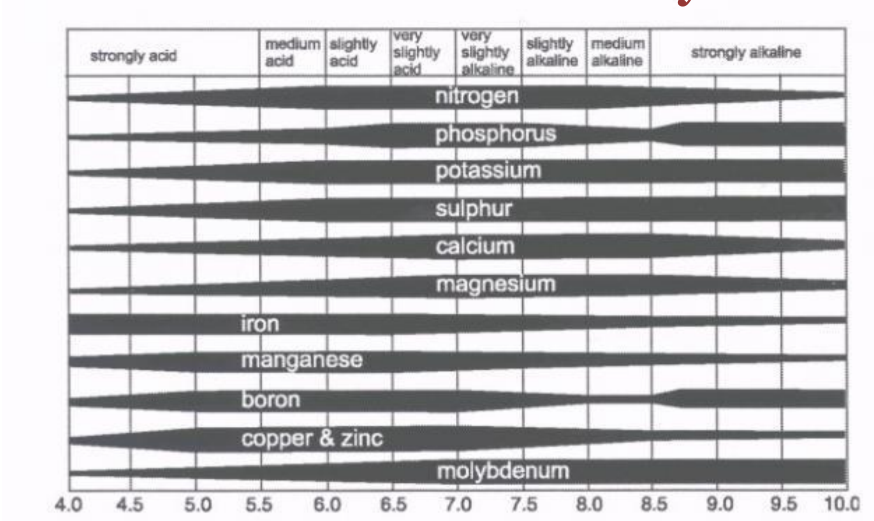
Chemical Components of Soil

pH: concentration of H^+ activity relative to OH^-

- impacts nutrient availability



Nutrient Availability



Interpreting Soil Tests

- Does not factor in availability
- Critical values may vary by lab (recommendations are computer generated)

Crop Grown: GRAPES

Analysis	Results	CL*	Units	ExLow VLow Low Mod High VHigh Excess.	Fertilizer Recommended
pH	4.5	(5.8)	-	Strongly Acid	
Conductivity	84	(-)	umho/cm	None	
Nitrate-N	14	(-)	ppm		0 lbs N/acre
Phosphorus	65	(50)	ppm		0 lbs P2O5/acre
Potassium	102	(150)	ppm		15 lbs K20/acre
Calcium	681	(180)	ppm		0 lbs Ca/acre
Magnesium	102	(50)	ppm		0 lbs Mg/acre
Sulfur	17	(13)	ppm		0 lbs S/acre
Sodium	63	(-)	ppm		
Iron	204.44	(4.25)	ppm		
Zinc	2.12	(0.27)	ppm		0 lbs Zn/acre
Manganese	19.54	(1.00)	ppm		0 lbs Mn/acre
Copper	0.27	(0.16)	ppm		0 lbs Cu/acre
Boron	0.21	(0.60)	ppm		1 lbs B/acre
Limestone Requirement					1.00 tons 100ECCE/acre
Limestone Requirement (Chemical Test)					1.2 tons 100ECCE/acre
Organic Matter	2.28		%		

Detailed Salinity Test (Saturated Paste Extract)		
pH	5.4	
Conductivity	0.39 mmhos/cm	
Sodium	50 ppm	2.160 meq/L
Potassium	18 ppm	0.448 meq/L
Calcium	29 ppm	1.455 meq/L
Magnesium	7 ppm	0.578 meq/L
SAR	2.14	
SSP	46.55	

*CL=Critical level is the point which no additional nutrient (excluding nitrate-N, sodium and conductivity) is recommended.

Potential for Deficiency

<u>High pH Soils:</u>

Iron

Zinc (unavailable at ≥ 9)

<u>Sandy Soils:</u>

Potassium

Others

Rootstock and Soil Adaptability

Rootstock	Drought Tolerance	Tolerance to Poorly Drained Soils	Lime Tolerance	Salinity Tolerance	Soil Adaption
SO4	Low	Medium	Medium	Low	Loams, clays, sandy clays
5BB	Medium	Low	Medium	Medium	Sandy clays, loams, clays
5C	Low	Medium	Medium	Medium	Finely textured soils
110R	High	Low	Medium	Medium	Coarse soils
1103P	Medium	Medium	Medium-High	Medium	Widely adapted
Freedom	Medium	Low	Medium	Medium	Sandy, well-drained
Harmony	Medium	Low	Medium	Medium	Coarse, well-drained
Salt Creek	Medium	Medium	Medium	High	Light sandy, infertile
Dog Ridge	Medium	Medium	Medium	Low	Sands, clay loam, neutral to mildly alkaline
101-14 Mgt	Low	Medium	Low	Low	Sands to clays, neutral pH
3309C	Low	Medium	Low	Low	Deep, well-drained
Riparia Gloire	Low	High	Low	Low	Acid soils

Adapted from: Growing Grapes in Texas, J. Kamas

Organic Matter

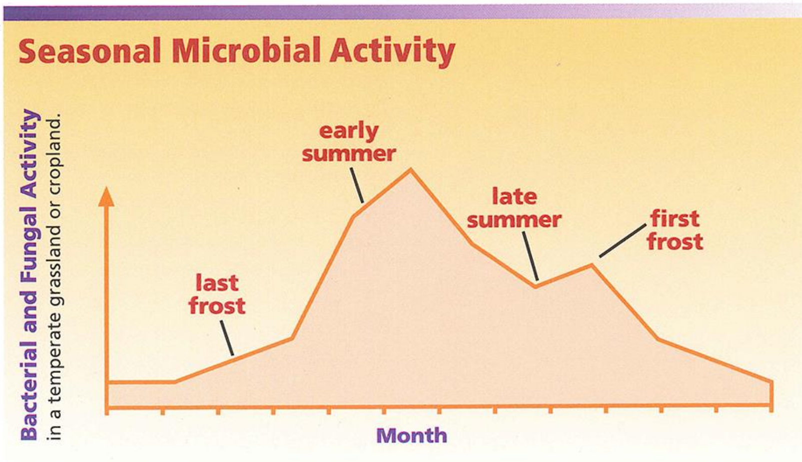
- Decomposed plants, animals, and microbes
- Slow release of nutrients
- Variable composition

Organic Matter Composition

Organic Matter Source	Nitrogen*	Phosphorus	Potassium	C:N Ratio
Cotton seed meal	7.7	2	1	7
Dry Chicken Litter	2.0-4.5	4.6-6	1.2-2.4	12-15
Dry Steer Manure	0.6-2.5	0.7-1.1	2.4-3.6	11-30
Poultry Compost	0.9	1.95	1.15	11
Wood Chips	0.1-0.5	-	-	80-400
Grape Pomace**	1-2	2-3	0.1-0.3	<30

*percent by weight
**from: Patti et al., 2004

Faster decomposition in South



USDA-NRCS, Soil Food Web

Microbial Activity

"There are more soil microorganisms in a teaspoon of healthy soil than there are people on the earth" -USDA-NRCS

- **Lactic acid-producing bacteria**
- **Mycorrhizal fungi**
- **Rhizobium bacteria**
- **Nitrobacter**
- **Beneficial nematodes**

Mulching

Benefits: soil moisture preservation, temporary weed control, organic matter

Disadvantages: soil moisture preservation, nutrients?, $$$

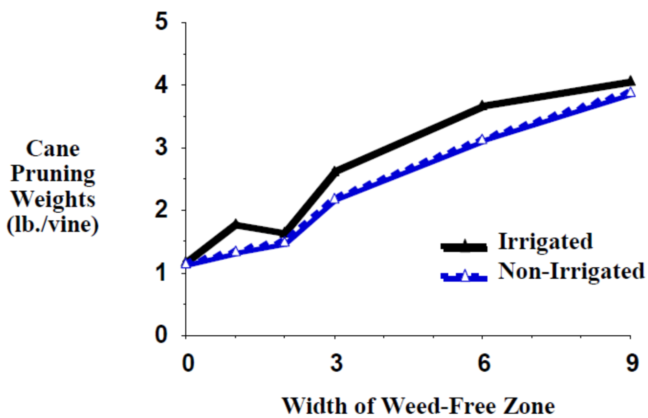
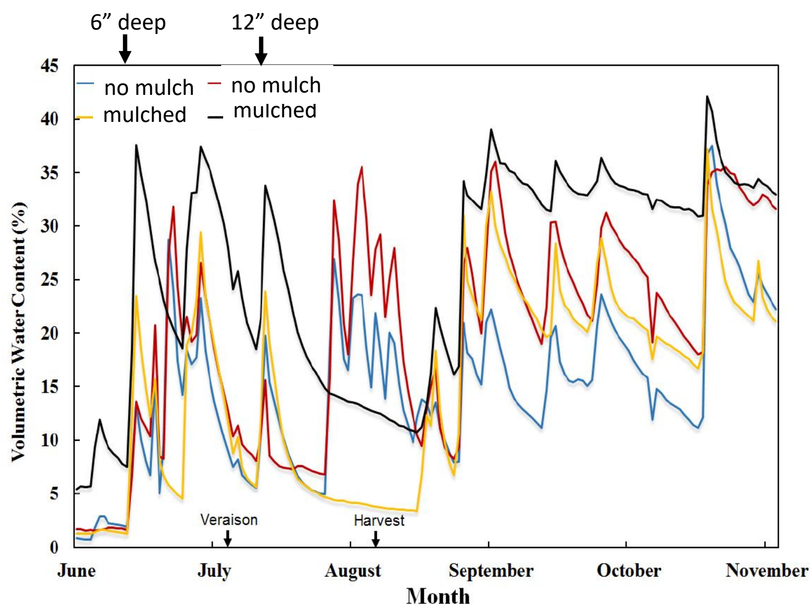


Figure 2. Effect of width of weed-free zone and irrigation on 1998 cane pruning weight (courtesy Alan Lakso).



Soil Salinity

Guidelines for Interpreting Soil Suitability for Vineyards

Analysis (Salinity)	No Problem	Increasing Problem	Severe Problem
EC dS/m or mmho/cm	1.5 to 2.5	2.5 to 4.0	4.0 to 7.0
TDS ppm or mg/L	960 to 1600	1600 to 2560	2560 to 5600
Sodium ppm or mg/L	-	>690	-
Chloride ppm or mg/L	<350	350-1060	>1060
Boron ppm or mg/L	<1	1-3	>3

Salinity in Irrigation Water

Guidelines for Interpreting Irrigation Suitability for Vineyards

Analysis (Salinity)	No Problem	Increasing Problem	Severe Problem
EC dS/m or mmho/cm	< 1	1.0 to 2.7	>2.7
TDS ppm or mg/L	<640	640 to 1728	>1728
Sodium ppm or mg/L	<460	-	-
Chloride ppm or mg/L	<140	140-525	>525
Boron	<1	1-3	>3

Potential severity is a general guideline and will vary by:
- soil type
- rainfall
- irrigation frequency

Toxicity symptoms often include marginal leaf burn and stunted growth.

Sodium adsorption ratio (SAR)

- ratio of activity of sodium to calcium and magnesium
- calcium and magnesium compete with sodium for exchange sites

$$SAR = \frac{Na^+}{\sqrt{(Ca^{++}+Mg^{++})/2}}$$

Guidelines for Interpreting Irrigation Suitability for Vineyards

Analysis	No Problem	Increasing Problem	Severe Problem
SAR	< 6	6 to 9	>9

***High levels of carbonate and bicarbonate increase sodium hazard of water**

Exchangeable sodium percentage (ESP)

- Percentage of CEC in soil occupied by sodium

Analysis	No Problem	Increasing Problem	Severe Problem
ESP	<10	10 to 15	>15

Leaching

- Natural rainfall
- Irrigation in excess of vine needs
- Subsurface drainage below root zone
- Addition of soil amendments (Calcium)

Reclamation should be conducted when soil salts reach threshold

- Winter months, following significant rainfall is more practical

Leaching Requirement

L_r = Leaching requirement (how much water is needed to leach salts)

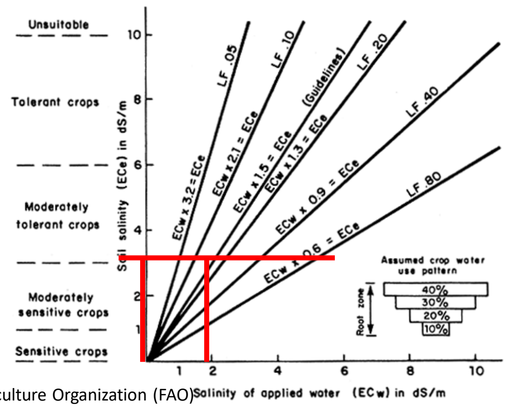


Figure from: Food and Agriculture Organization (FAO)

Gypsum

Gypsum ($CaSO_4 \cdot 2H_2O$) banded under vine row or injected

- calcium exchanges with sodium on soil exchange sites
- sodium can be leached beyond rooting zone

Gypsum Rate Based on Exchangeable Sodium Percentage

Soil Texture	Exchangeable Sodium Percentage					
	10	15	20	30	40	50
	Gypsum (tons per acre)					
Coarse	1.1	1.7	2.3	3.4	4.6	5.7
Medium	1.9	2.9	3.8	5.7	7.7	9.6
Fine	2.7	4.0	5.4	8.0	10.7	9.6

4 The University of Arizona Cooperative Extension

Table from: Arizona Cooperative Extension (AZ 1413)

Non-traditional Soil Additives

Three major categories:

1. Soil conditioners or activators
2. Biological inoculants
3. Wetting agents

Benefits of Humic Acids?

- Soil Physical Benefits:
  - Benefits of addition of organic matter has long been documented in agriculture
- Soil Chemical Benefits- Sequestering Agent
- Soil Biological Benefits?
  - Increased Food Source for Microbes?
    - App of 5-20 gal/A of Humic Material Provides 3-15 lbs of C/Acre
    - Typical Corn Stubble Residue provides 4000 lbs C/Acre

The addition of 2,000 per acre of humates would increase the organic material of a soil by 0.1%

Biological Conditioners

Examples:

Mycorrhizae: fungi that live either on in or plants roots and effectively extend the reach of the root hairs

- Potential benefits:
  - nutrient uptake
  - reduced nematode feeding
  - disease suppression

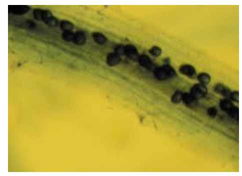


Image from: urbanext.illinois.edu/

- Dozens of mycorrhizae species occur in nature

Rhizobia (fix nitrogen from the air)

- only in legumes

Wetting Agents

Break down the natural surface tension in water

- promoted as improving water penetration in soil, drainage, and soil structure; control erosion and reduce compaction
  - have no effect on poor drainage due to hardpans, compaction due to tillage or traffic, and fine textured soils with very small pores (Hall and Sullivan, 2001)

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