Mineral Deficiencies, Toxicities, Diagnosis, and Corrections

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What is an essential nutrient?

- A component of plant structures, or involved in plant metabolism, whose absence results in:
  - Cell death
  - Severe abnormalities
  - An inability to complete its life cycle (successfully reproduce)

What are the essential nutrients?

- Macronutrients:
  - Primary
    - Nitrogen
    - Phosphorus
    - Potassium
  - Secondary
    - Calcium
    - Magnesium
    - Sulfur
- Other:
  - Carbon
  - Hydrogen
  - Oxygen

- Micronutrients:
  - Iron
  - Manganese
  - Boron
  - Copper
  - Zinc
  - Molybdenum
  - Nickel

Nutrient Mobility

- Soil mobile
  - Nitrogen (NO_3^-)
  - Sulfur
  - Boron
- Soil immobile
  - Phosphorus
  - Calcium
  - Magnesium
  - Potassium: mobility dependent on soil texture
  - Zinc
  - Manganese
  - Copper
  - Iron

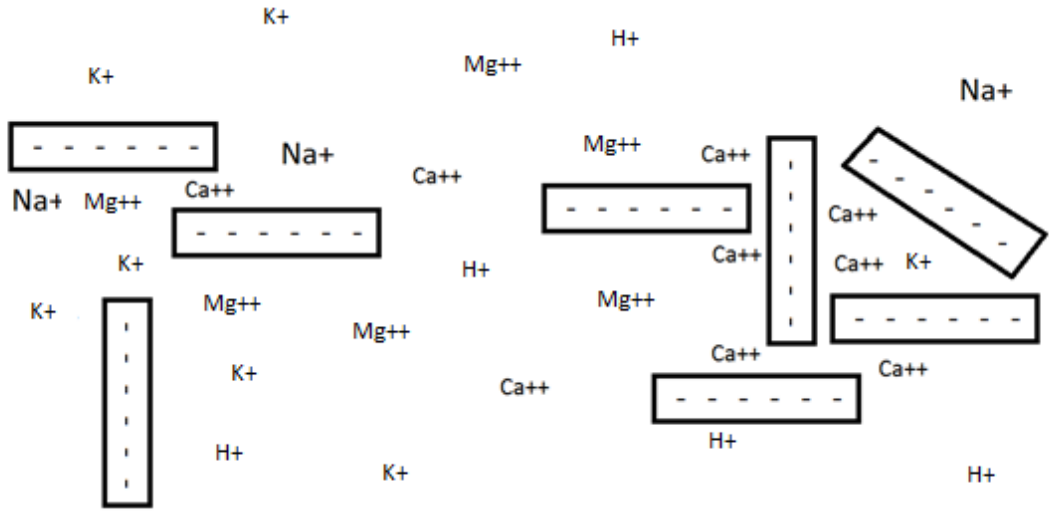
- Plant mobile
  - Nitrogen
  - Phosphorus
  - Potassium
  - Magnesium
- Plant immobile
  - Boron: species dependent
  - Sulfur
  - Calcium
  - Zinc
  - Manganese
  - Copper
  - Iron

Nutrient Uptake in Plants

- Roots are taking up nutrients (generally) when leaves are on the trees
- Roots have a limited ability to take up nutrients in saturated conditions
- Roots can only take up nutrients from the soil solution
- Roots can only explore a tiny proportion of the soil surface area

Cation Exchange Capacity

- The Cation Exchange Capacity (CEC) is the soil's ability to hold onto positively charged ions
- Dependent on the amount and type of clay as well as organic matter
- Inherent property of soils
- The size of the CEC determines how many cations (nutrients) your soil can hold



Cation Exchange Capacity

- NH_4^+
- K^+
- Mg^{2+}
- Ca^{2+}
- Na^+
- H^+
- Al^{3+}
- Other cations

- Anything positively charged can bind to the CEC
- Cations are not permanently bound to the CEC
- Soils with large CECs can hold more nutrients than soils with small CECs

Nutrient Availability in Soils - pH

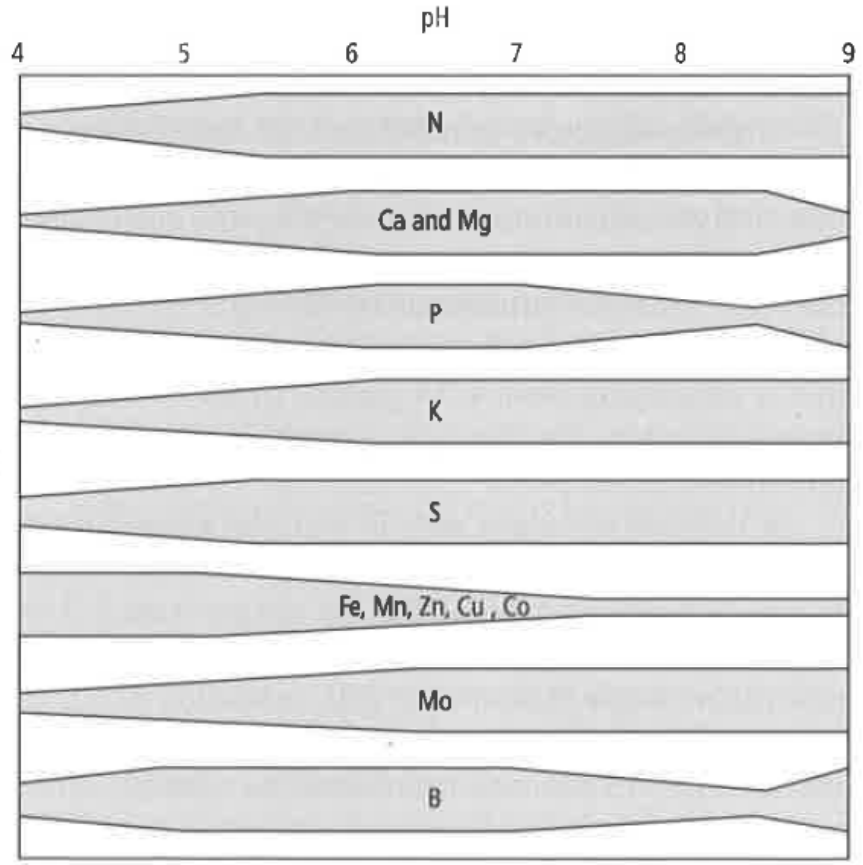


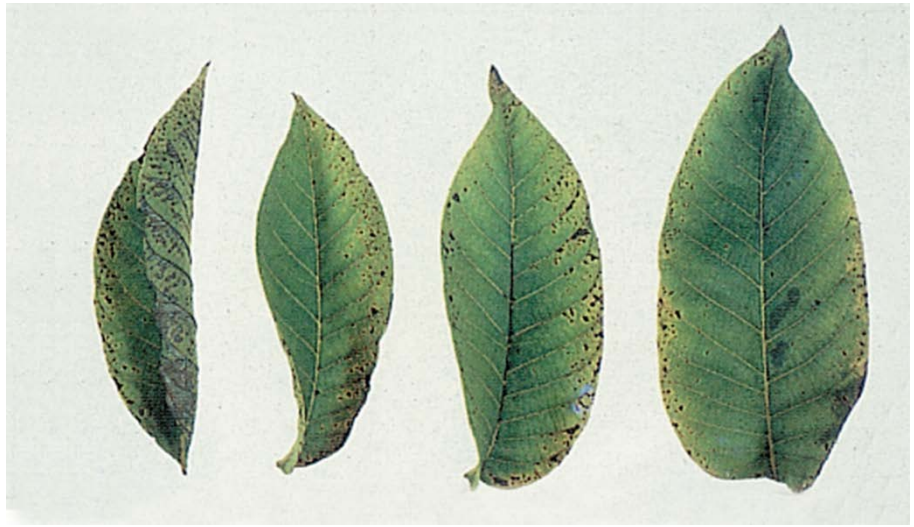
Figure 24.1 Effect of soil pH on relative availability of plant nutrients. A broad bar indicates high relative availability while a narrow bar indicates low availability.

- Nutrient availability is pH dependent
- The greatest availability of nutrients is between pH of 6 and 7.5

Potassium

- Found in the soil in:
  - Soil minerals – mica, e.g.
  - Adsorbed to CEC
  - In the soil solution
- Taken up as K+
- Used by the plant in:
  - Involved in plant water status maintenance
  - Activates enzymes

Potassium

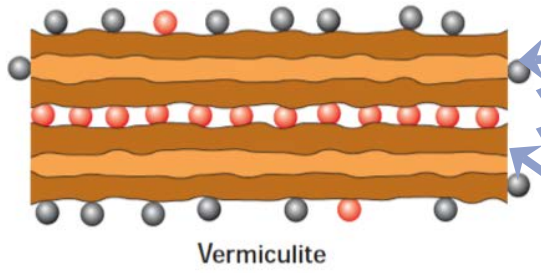


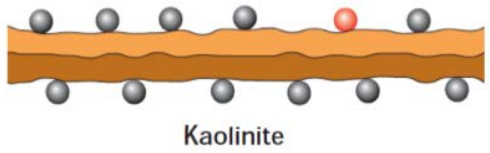
- Mobile in walnuts
- Pale older leaves
- Leaf edges fold up, curl in
- Leaf undersides develop grey cast
- Necrotic spotting on margins
- Leaf size, shoot growth reduced
- Nut size reduced

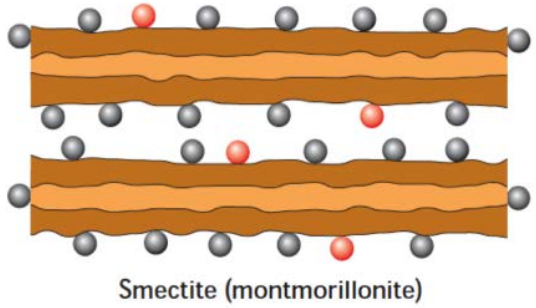
Potassium Fertilization

- 35-40 lbs K removed with 1 ton nuts
  - Only 12 lbs removed if hulls are returned to the field
- Fertilization only needed if deficiency symptoms present, or if growing in sandy or K fixing soils
- In sandy soils
  - Band, drill or fertigate 400 lbs/acre of K (for example, 900 lbs K_2SO_4)

Potassium Fixation: a special concern in Vermiculite rich soils







Potassium cation

Other cations

Clay minerals

K-Fixing Soils

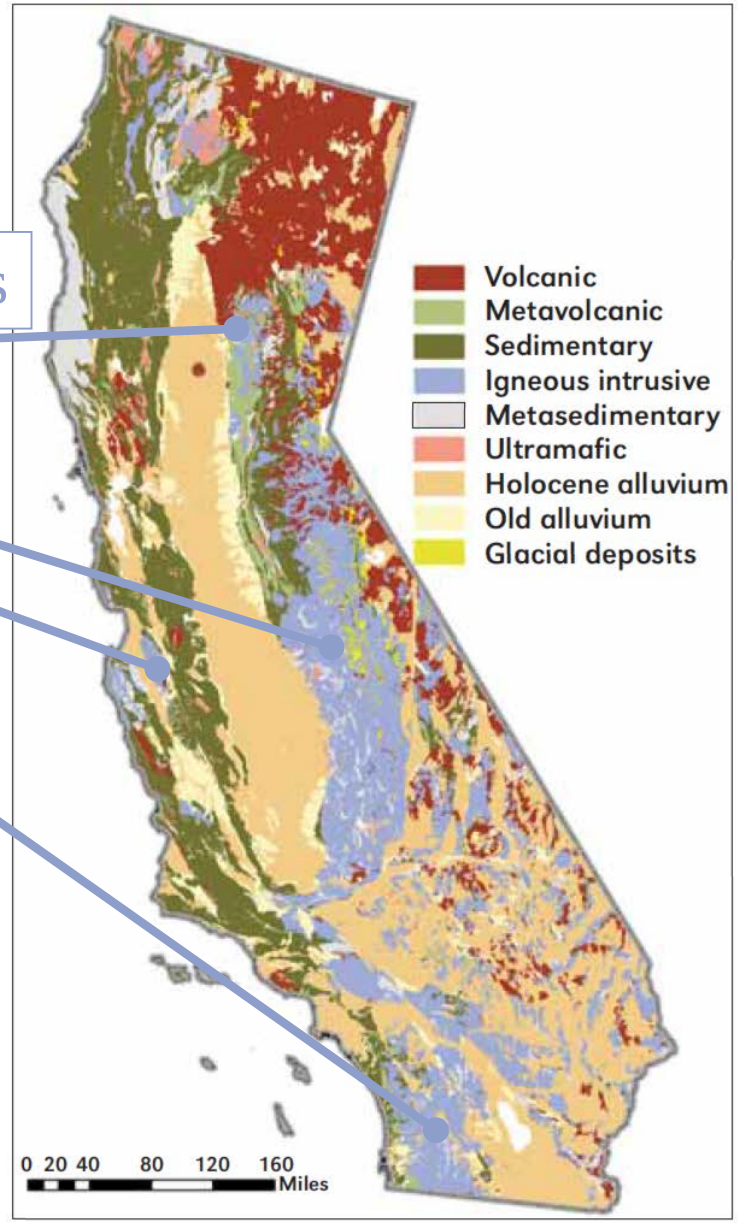


Figure 3. The soils of the Central Valley of California are primarily derived from granitic material from the East and sedimentary material from the West. Potassium-fixing soils are typically associated with granitic (igneous intrusive) parent material.

Slide credit: J. Caprile

Pettygrove et al, Better C

Potassium Fertilization

- 35-40 lbs K removed with 1 ton nuts
  - Only 12 lbs removed if hulls are returned to the field
- Fertilization only needed if deficiency symptoms present, or if growing in sandy or K fixing soils
- In sandy soils
  - Band, drill or fertigate 400 lbs/acre of K (for example, approx. 900 lbs K_2SO_4)
- In K fixing or clay soils
  - Band an initial application of 650 lbs K (for example, approx. 1500 lbs K_2SO_4)
  - Continue yearly maintenance applications of 200 lbs K/acre (approx. 400 lbs K_2SO_4 for example) until deficiency is remedied

Zinc

- Found in the soil:
  - Adsorbed and bound to other compounds (notably $CaCO_3$)
  - In the soil solution (in very low concentrations)
- Taken up as Zn^{2+}
- Used by the plant in:
  - Enzyme catalyst for more than 300 enzymes
  - Involved in auxin biosynthesis

Zinc

Photo: B. Beede

- Immobile in walnuts
- Delayed opening of buds
- Small, chlorotic tufts of leaves, small nuts
- Interveinal chlorosis
- Wavy leaf margin
- Terminal dieback
- Increased oxidation in nuts

Zinc

Photo: B. Beede

Zinc Fertilization

- Soil applications
  - Trench 5-10 lbs $ZnSO_4$ per tree
  - Inject 5-20 gallons $ZnSO_4$ sulfate solution (1 lbs $ZnSO_4$ per gallon water) into the root zone
  - Broadcast 1-5 lbs zinc chelate pre-irrigation
  - Trench 10 lbs $ZnSO_4$ per tree and cover with 5 lbs sulfur in high pH soils
- Foliar applications
  - Mix 1-2 lbs of $ZnSO_4$ or zinc chelate in 100 gallons of water
  - Application rate should be 2-4 lbs Zn/acre
  - First application: just post bloom, when new growth is 6-10 inches long
  - Repeat a second or third time in 2-3 week intervals

Boron

- Found in the soil:
  - Adsorbed to clays, metal oxides, and organic matter
  - In the soil solution
- Taken up as $B(OH_3)$
- Used by the plant in:
  - Structural integrity of cell walls
  - Membrane function
  - pollination

Boron

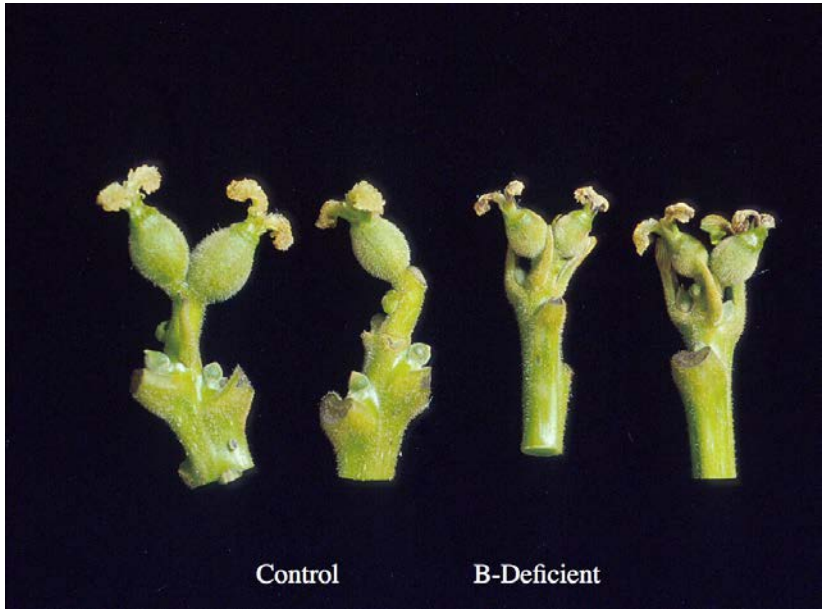


Photo: P. Brown

- Weak growth
- Short internodes
- Misshapen leaves
- Terminal dieback
- Low yields

Boron Fertilization

- Soil application
  - Broadcast 50-75 lbs Borax per treated acre
- Foliar application
  - spray a mixture of 1 lbs Solubor per 100 gallons of water
  - Timing can be any time of the year, but best done during delayed dormancy or in the early growing season
    - Spraying during bloom can negatively affect pollen movement and flower health

Boron Toxicity

- Necrosis of the leaf tip and margins
- That appears in mid-late summer as levels accumulate in leaves
- Leaf curl and scorching of the entire canopy in severe cases

Boron Toxicity

- Switch to a low boron water source
- Leach from root zone
- Use tolerant rootstocks
  - Black most tolerant
  - English least tolerant
  - Paradox is in between
- Plant a tolerant crop

Chloride Toxicity

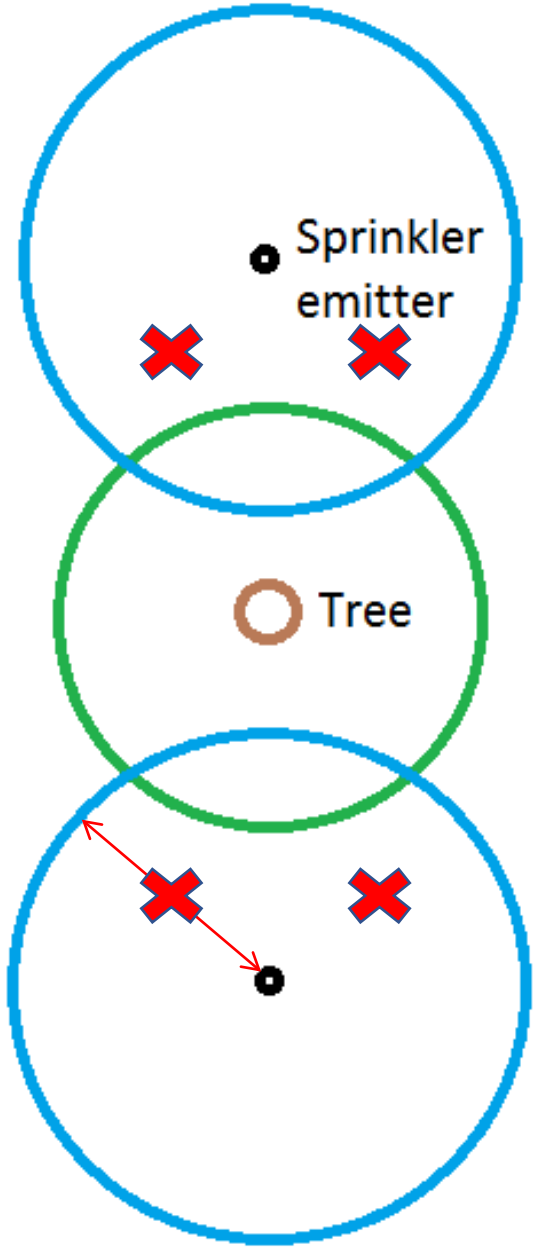
- Symptoms similar to boron toxicity
- Switch to higher quality water
- Leach (easily removed)
- Plant tolerant rootstocks
  - Black most tolerant
  - English least tolerant
  - Paradox in between
- Plant more tolerant crops

Soil Sampling

- Pre-planting soil sampling
  - Necessary for accurate picture of orchard
  - Samples should be to reasonable depth of rooting zone
- Routine soil sampling
  - Good for monitoring K, B, Na, Cl

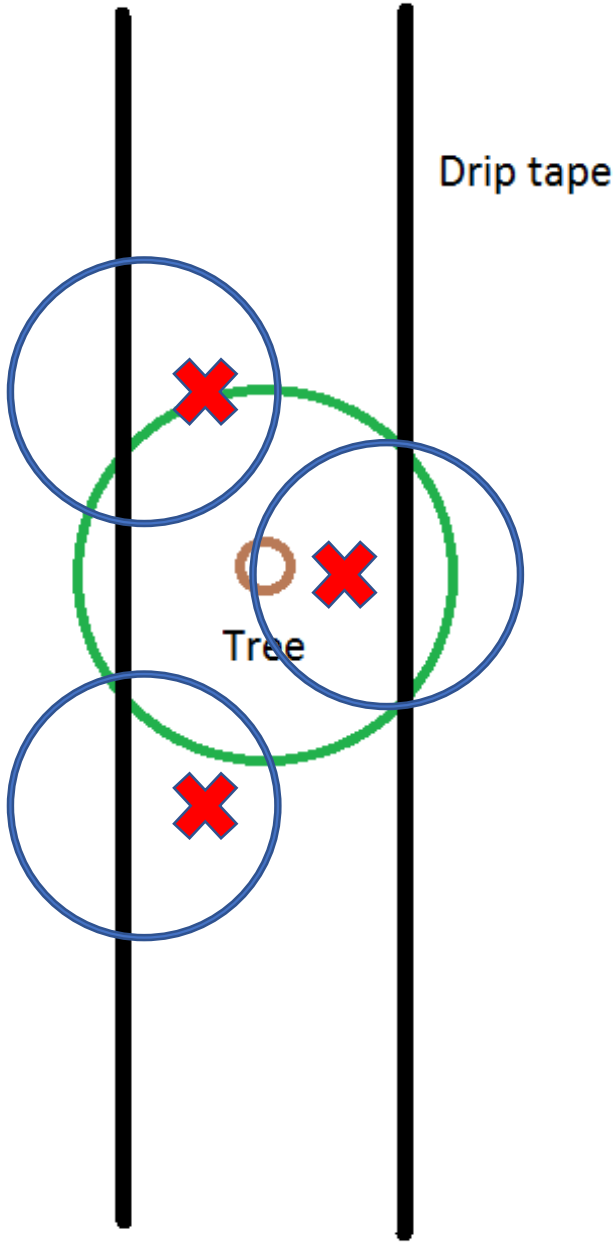
Soil Sampling

- Sample 0-12 inches, discarding surface debris
- Pull samples from ½ to ¾ of the wetted radius



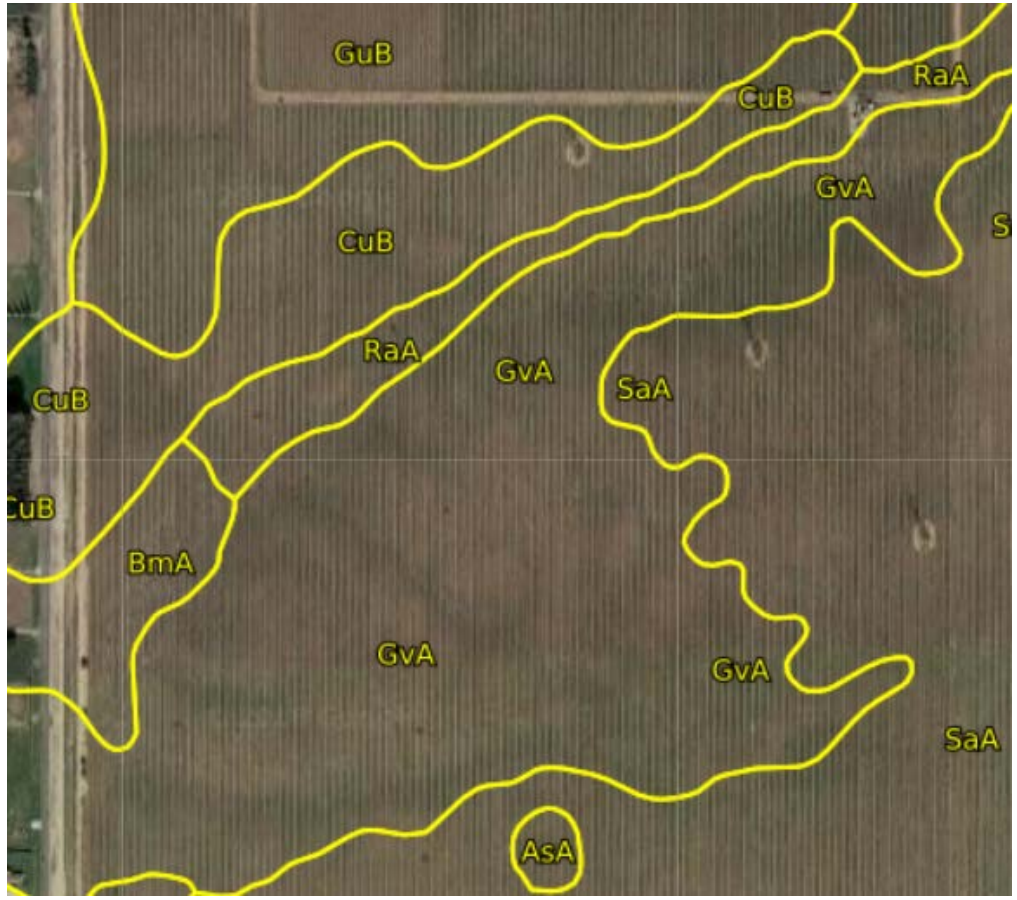
Soil Sampling

- Sample 0-12 inches, discarding surface debris
- Pull samples from ½ to ¾ of the wetted radius
- Pull 8 to 12 subsamples for each sample
- Mix them WELL and send in one pound to a lab



Soil Sampling

- Don’t combine soil types
- Don’t combine irrigation blocks
- Don’t combine good and bad areas



Leaf Sampling

- Test yearly in July
- Useful for monitoring all nutrients
  - Exception: recent foliar micronutrient sprays
- Select terminal leaflet from 30-50 leaves on 20-30 trees
  - Don’t combine symptoms
  - Don’t combine soil types
  - Don’t combine irrigation blocks
  - Don’t combine varieties

Leaf Sufficiency Values

Nutrient	Deficient	Sufficient	Toxic
Nitrogen	< 2.1%	2.2 – 3.2%	N/A
Potassium	< 0.9%	> 1.2%	
Boron	< 20 ppm	36 – 200 ppm	> 300 ppm
Zinc	< 18 ppm		
Sodium			> 0.1%
Chloride			> 0.3%

Questions?

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