UC CE
UC Cooperative Extension
University of California
Agriculture & Natural Resources

Apple Orchard Nutrients, Irrigation & Dry Farming

By Ellie Andrews
UCCE Specialty Crops Advisor
Sonoma, Marin, and Napa Counties

(Devoto Orchards pictured here, Sebastopol)

Nutrient Management

- Need to maintain enough nutrients for healthy plant functioning & good yield

(Devoto Orchard, credit: Ellie Andrews)

Nutrient Management

- Need to maintain enough nutrients for healthy plant functioning & good yield
- Get nutrient status into a healthy range
- Replace the amount of nutrients that move out of the orchard at harvest in fruit

(goodeggs.com/devoto)

(Devoto Orchard, credit: Ellie Andrews)

Nutrient Management

- Which nutrients to apple trees need?

(Hale's Apple Farm, credit: Ellie Andrews)

Nutrient Management

- Which nutrients to apple trees need?

(Hale's Apple Farm, credit: Ellie Andrews)

<u>Macronutrients</u>
(need large amount)
Nitrogen
Phosphorus
Potassium
Sulfur
Calcium
Magnesium

<u>Micronutrients</u>
(need small amount)
Iron
Manganese
Copper
Zinc
Molybdenum
Boron
Chloride
Nickel

Nutrient Management

- Which nutrients to apple trees need?

(Hale's Apple Farm, credit: Ellie Andrews)

translocation (movement) across the tree

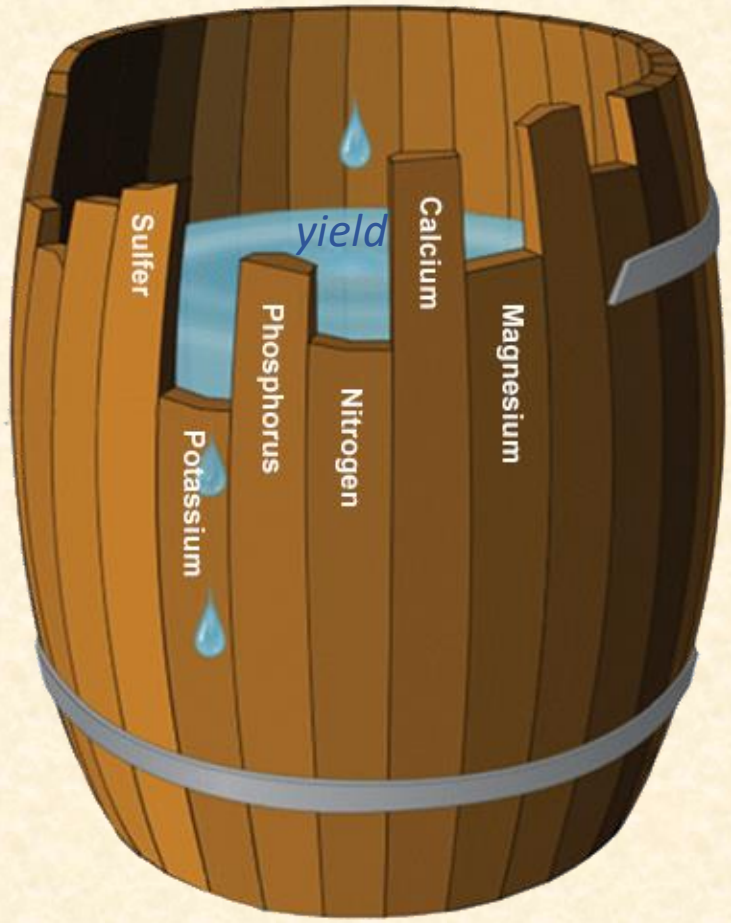
nutrient uptake by roots

<u>Macronutrients</u>
(need large amount)
Nitrogen
Phosphorus
Potassium
Sulfur
Calcium
Magnesium

<u>Micronutrients</u>
(need small amount)
Iron
Manganese
Copper
Zinc
Molybdenum
Boron
Chloride
Nickel

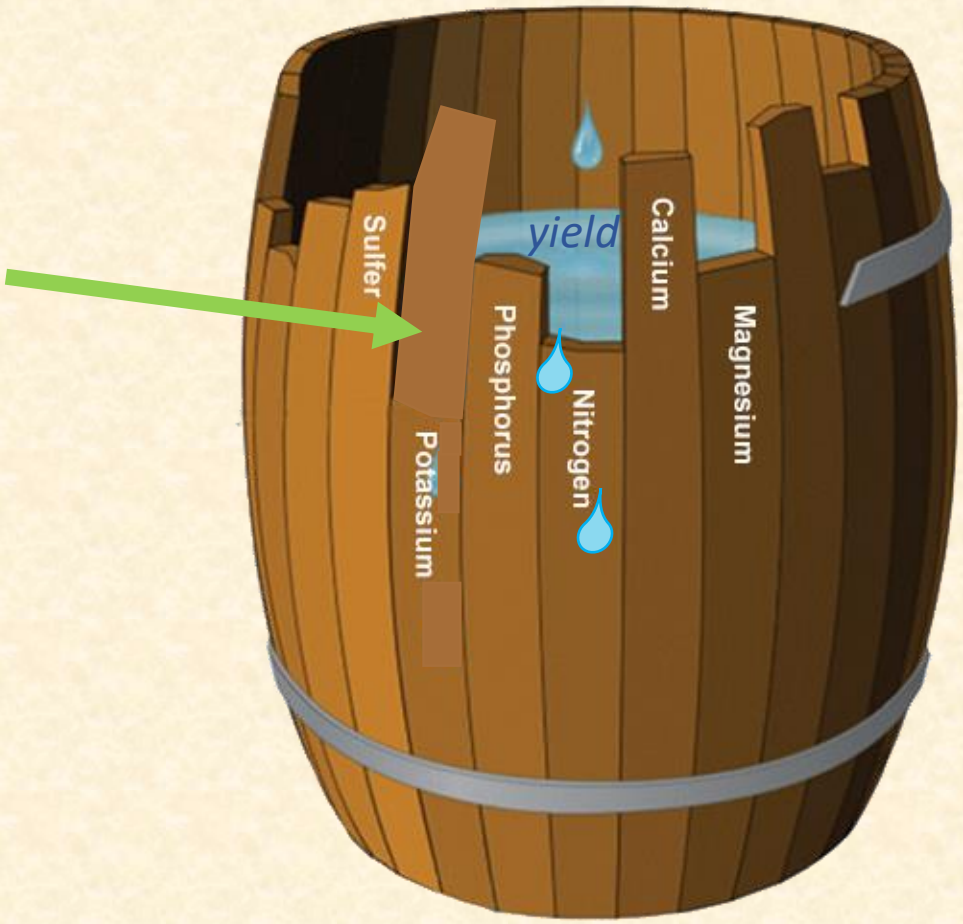
Nutrient Management

- Law of the Minimum
  - If one of the essential elements is low, plant health & yield will be low until that deficiency is lifted
  - Barrel metaphor: lowest stave represents the most limiting nutrient

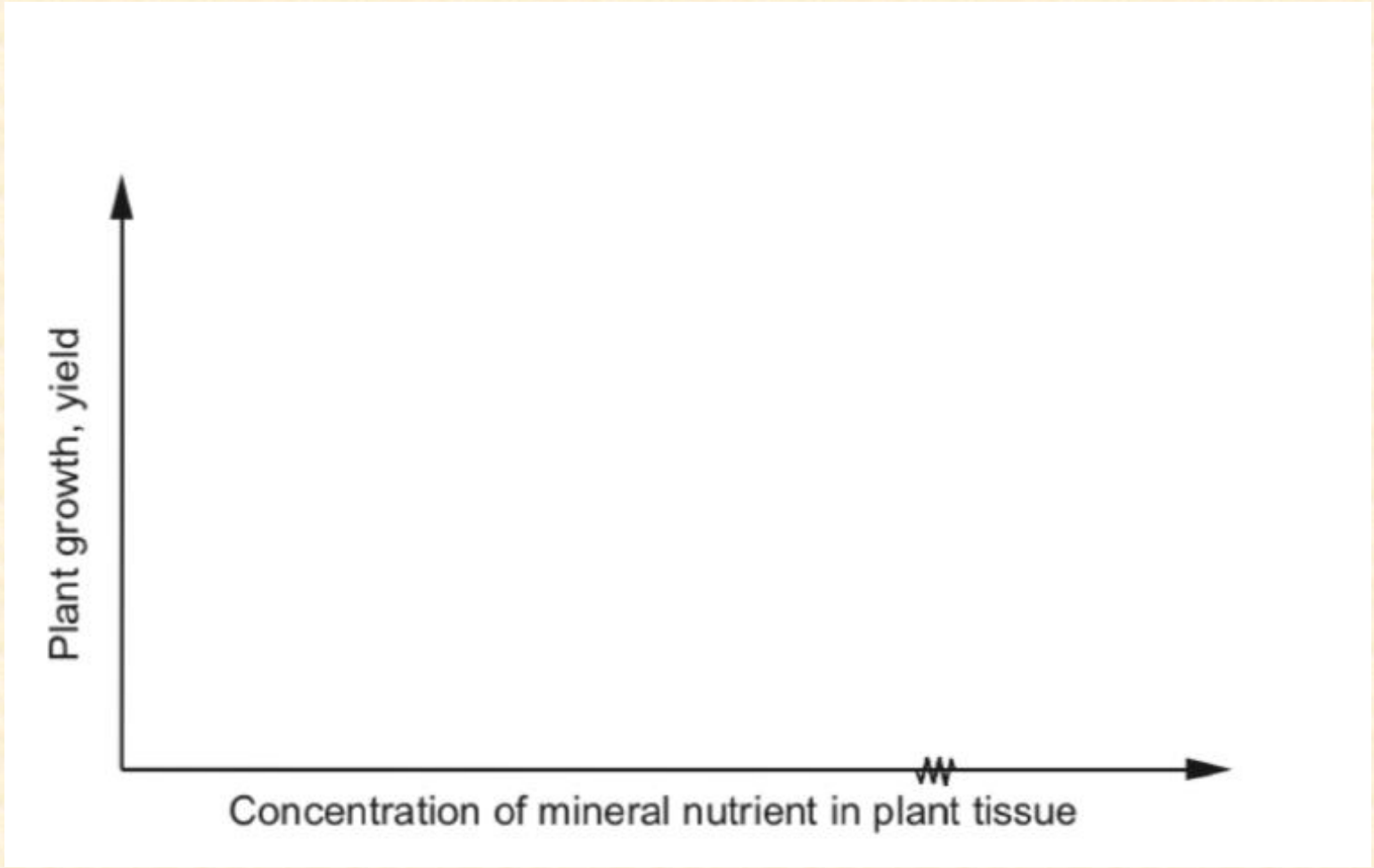


Nutrient Management

- Law of the Minimum
    - Supplying it increases the yield potential to the next most limiting factor

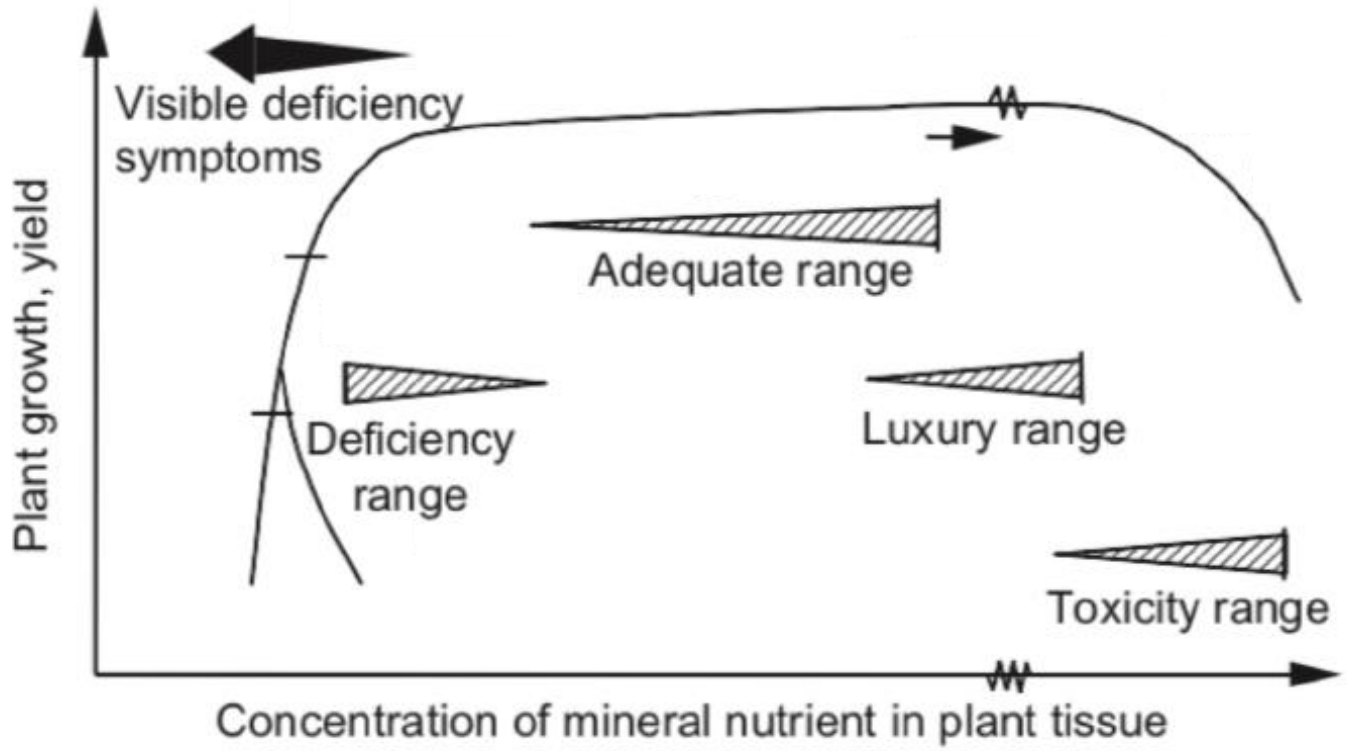


Rate

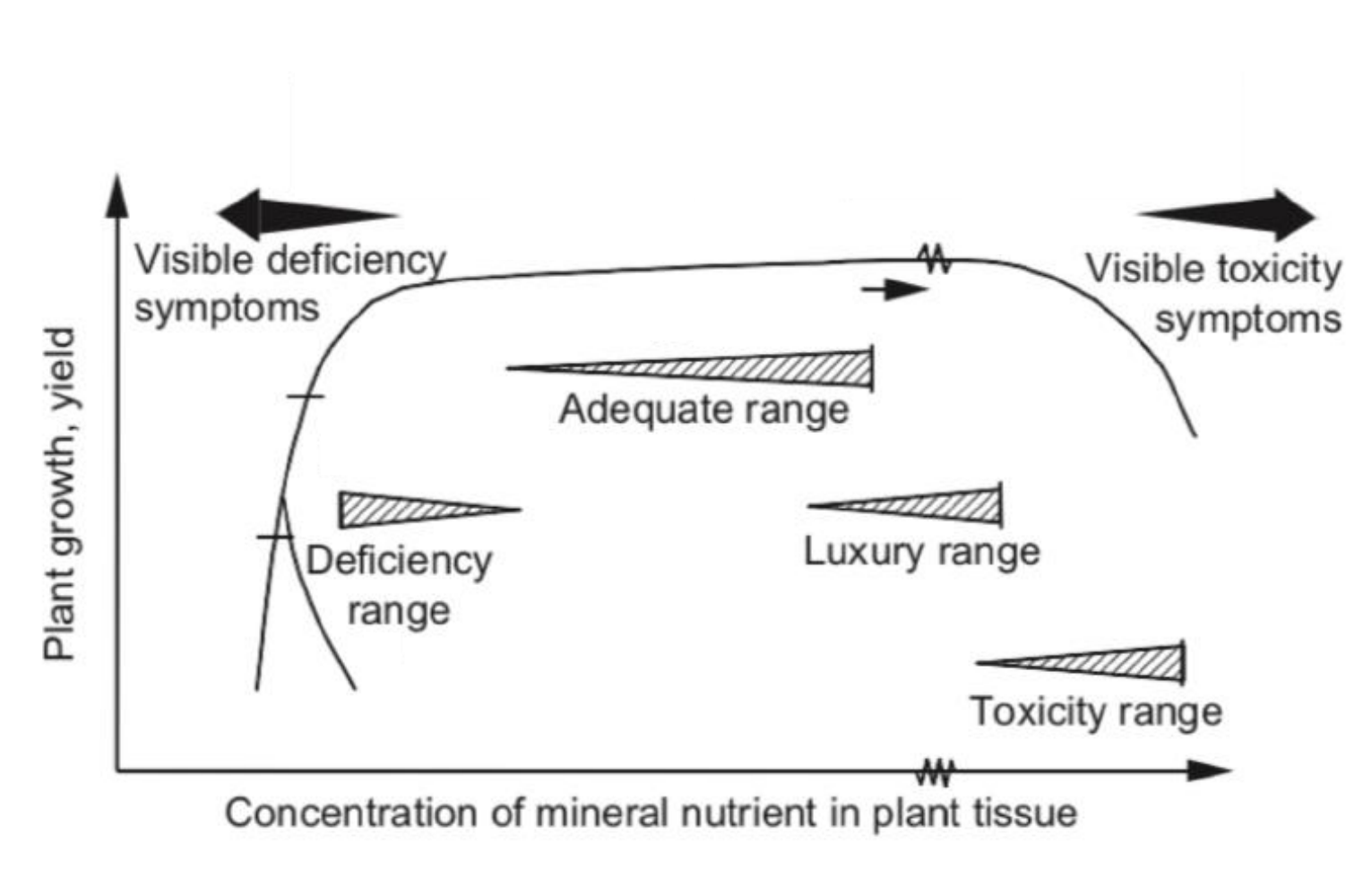

Plant growth, yield
Concentration of mineral nutrient in plant tissue

Rate

Deficiencies impair plant functioning & yield



Rate

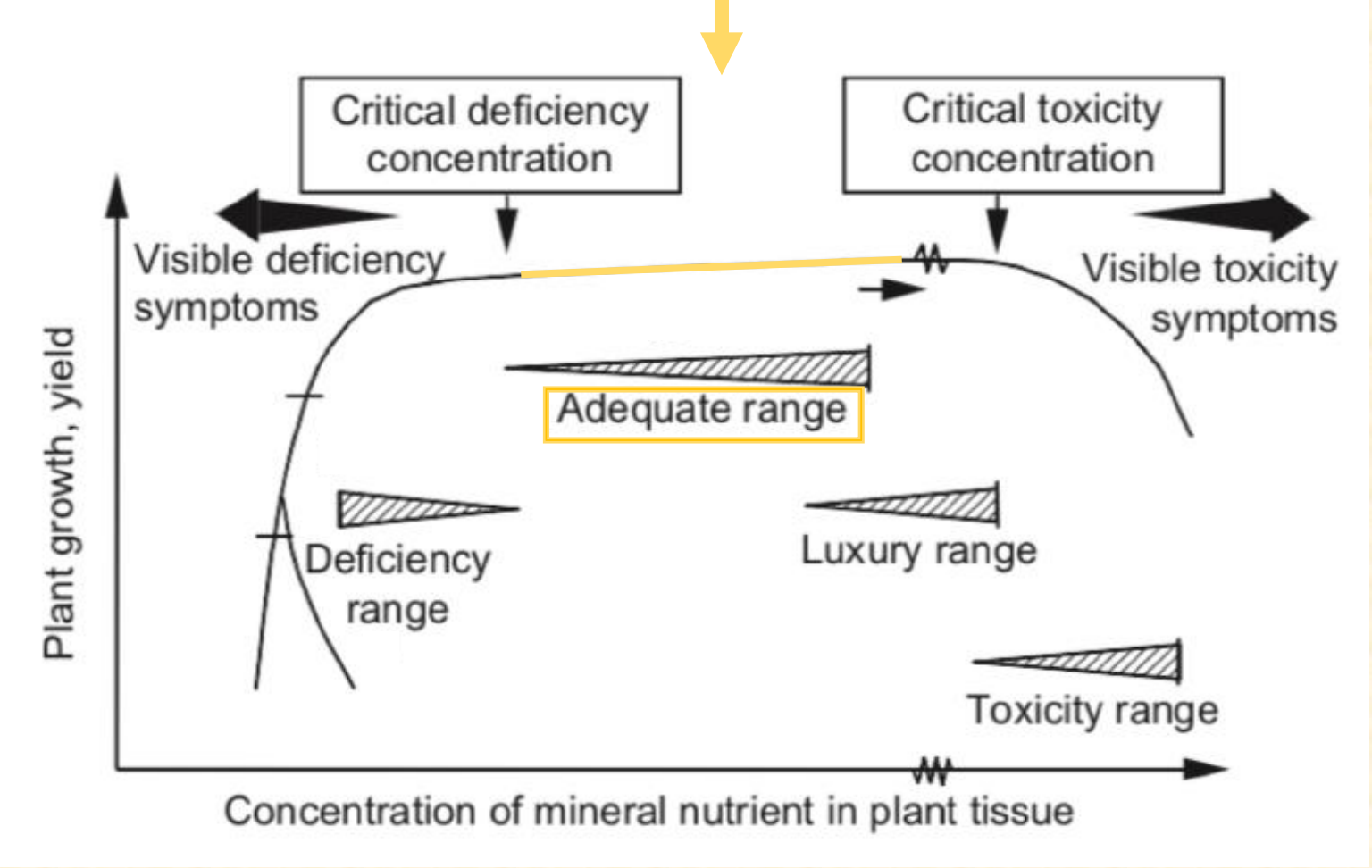


Over fertilizing can lead to

- excess vigor
- lower yield & quality
- environmental damage
- wasted money

Rate

Visual assessments & diagnostic tools help you keep tree nutrient status in the safe range



Rate

- Amount of nutrients needed depends on:
  - Scion & rootstock
  - Tree age & canopy size
  - Soil & plant nutrient status
  - Irrigated vs. dry farmed
  - High input vs. low input system
  - Yield demand
  - Nutrient concentration of sources

(Hale's Apple Farm, credit: Ellie Andrews)

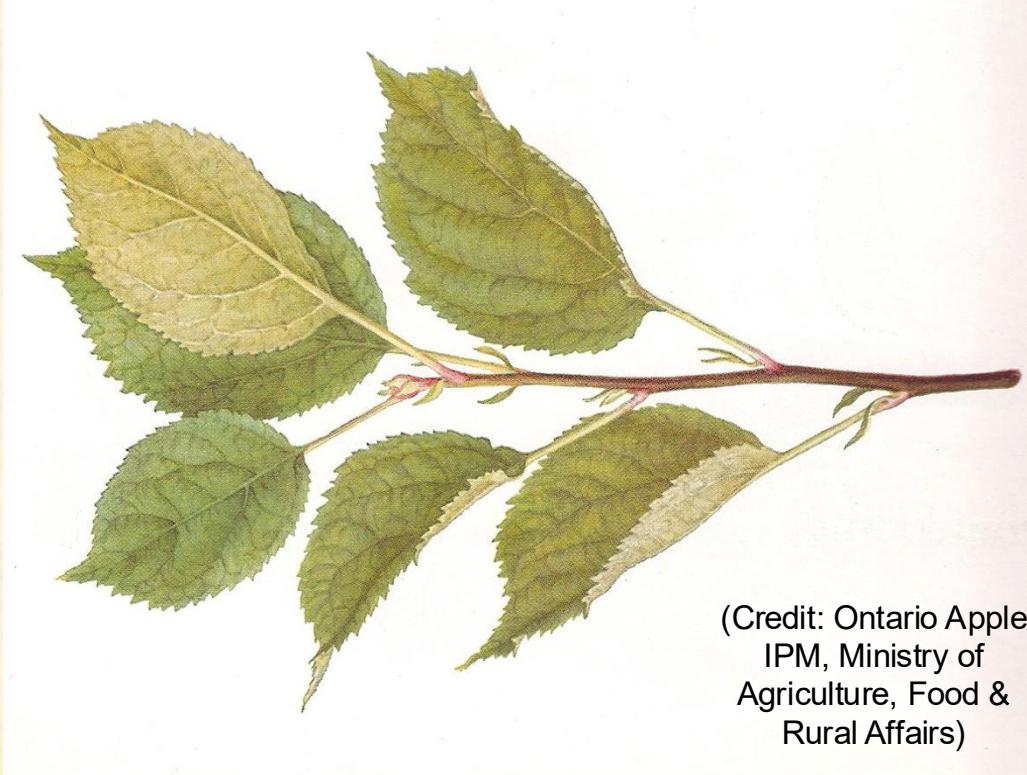
Visuals

- Nitrogen (N) deficiency symptoms
  - Appear on older leaves first
  - Uniform light green/yellow leaves (chlorosis)
  - Reduced leaf size
  - Thin, spindly, stunted shoot growth
  - Short terminal shoots

(Credit: Ontario Apple IPM, Ministry of Agriculture, Food & Rural Affairs)

Visuals

- Nitrogen (N) deficiency symptoms
  - If severe, older leaves may die
  - Reduced bud formation & fruit set
  - Small fruit size
  - Fruit that mature early
  - Reduced yield

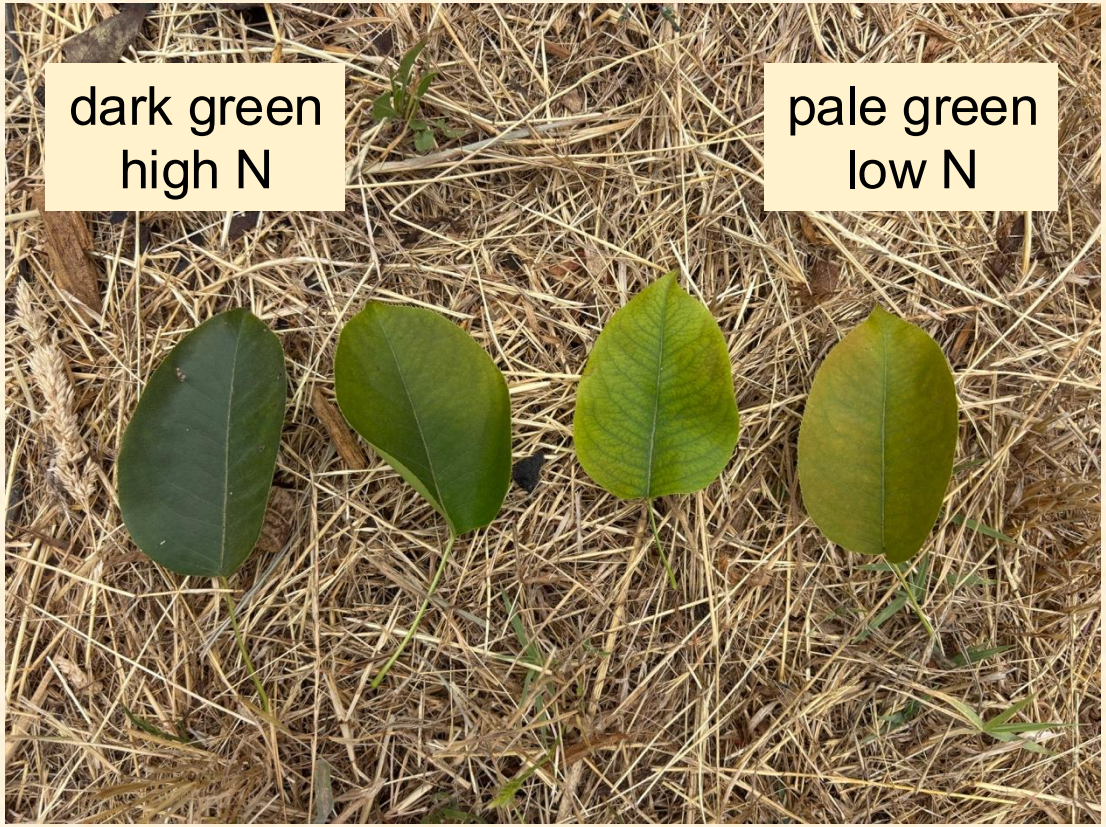


(Credit: Ontario Apple IPM, Ministry of Agriculture, Food & Rural Affairs)

(Credit: Eric Hanson, MSU)

Visuals

- Nitrogen excess symptoms
  - Large, dark green leaves that remain on the tree in late autumn
  - Excess foliage & vegetative growth
  - Increased susceptibility to fire blight
  - Reduced fruit quality, poor color
  - Fruit lose firmness faster in storage



(Credit: Ellie Andrews)

Visuals

- Potassium (K) deficiency symptoms
  - Appear on older leaves first, but can affect young leaves when severe
  - Yellowing of leaf margins can turn brown over time, curl upwards
  - May appear as fruit reaches maturity (fruit accumulate a lot of K)
  - K deficiency is more common in sandy soil than clayey soil

(Credit: Spectrum Analytics, UVM)

Potassium Deficient Apple

(Credit: Eric Hanson, MSU)

Visuals

- Calcium (Ca) deficiency symptoms
  - Aka bitter pit
  - Lesions often concentrated toward calix end of fruit
  - Small, corky, brown areas on fruit
  - Symptoms show up a few weeks before harvest or in storage

(Credit: Eric Hanson, MSU)

(Credit: Yara)

Visuals

- Zinc (Zn) deficiency symptoms
  - Small, chlorotic, long leaves
  - Sometimes interveinal chlorosis
  - Rosetting caused by short internodes
  - “Blind wood” on newer shoots

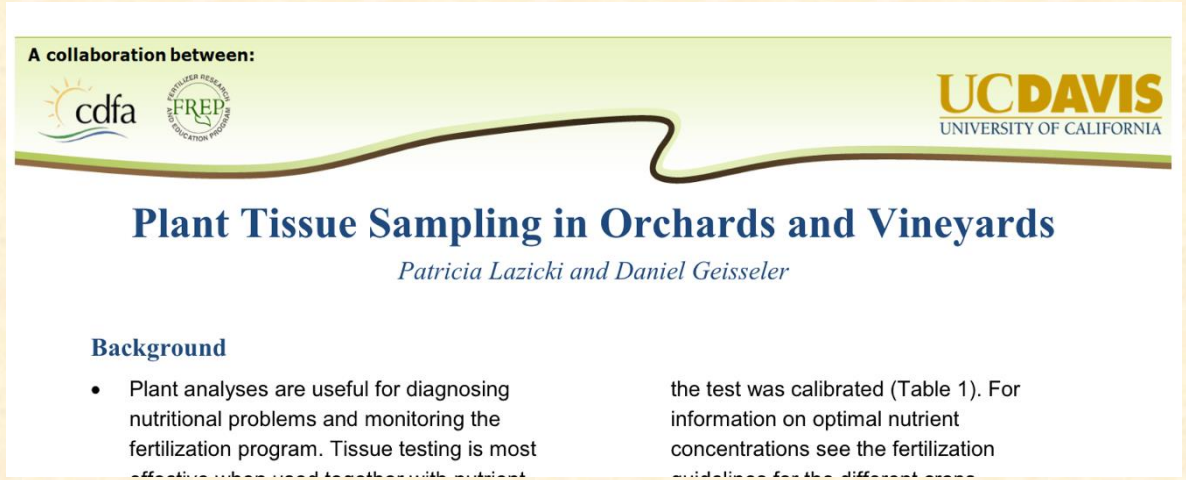
(Credit: Eric Hanson, MSU)

(Credit: Yara)

Leaf Sampling

- How do I know *for sure* if my trees have nutrient deficiencies?
- Collect leaves in July, send to a lab
- Leaf tissue analysis tells us the concentration of nutrients in apple leaves: the most reliable, direct assessment of tree nutrient status
- Directions: see CDFA website →

(Credit: Ellie Andrews)



Leaf Tissue Testing

- A quantitative assessment anyone can do
- Compare your results to the recommended ranges for apple trees →
- Are your results within the optimum ranges?

Table 3. Optimum and deficient levels of nutrients in apple leaves.

Nutrient	Optimum range	Deficient level
N (%)	2.0-2.6 1.8-2.4[1]	2.0
P (%)	.16-.30	0.11
K (%)	1.3-1.5	1.0
Ca (%)	1.1-1.6	0.5
Mg (%)	.30-.50	0.2
B (ppm)	25-50	25
Cu (ppm)	10-20	4**
Fe (ppm)	150-250	25
Mn (ppm)	50-80	20**
Zn (ppm)	20-40	15**

[1]Optimum range for soft varieties, e.g. Golden Delicious and Macintosh.
**indicates deficient levels is not well defined

(Credit: Eric Hanson, MSU)

Soil & Water Sampling

- Helps diagnose issues prior to planting & over time
- Understand nutrient availability & soil constraints
- Provides complementary info with leaf sampling, a full picture
- Helps guide fertilizer & amendment applications

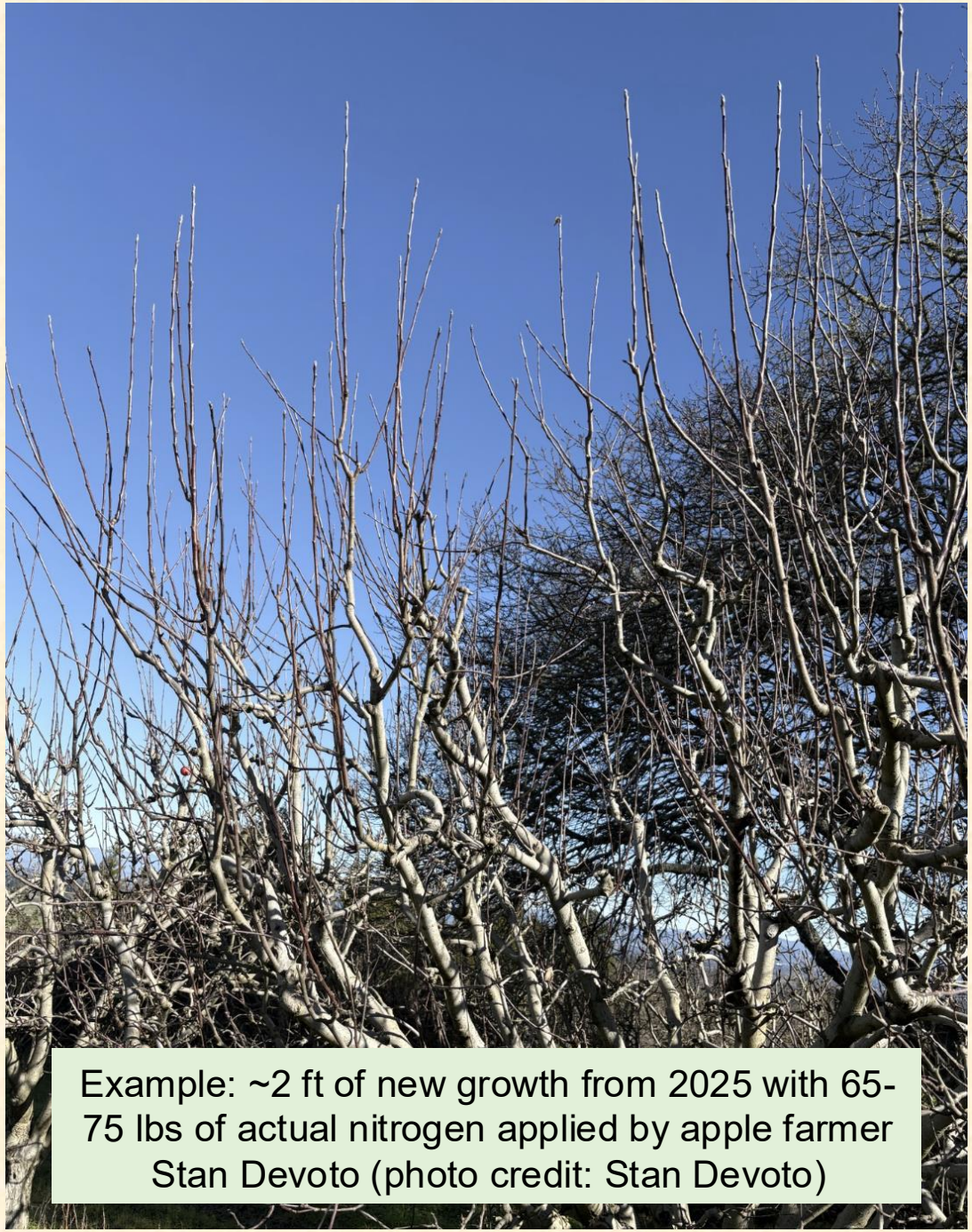
Nutrient Rates & Timing

- Big-Picture Goal: moderate tree vigor with minimal but sufficient nutrition
- Match timing of nutrient availability with crop demand, place in rootzone

(Credit: Ellie Andrews)

Nitrogen

- Might not need to apply N every year
- Apply as needed based on:
  - Vigor: goal is 18-30 inches shoot growth in young apple trees
  - Healthy bloom & fruit set
  - Leaf tissue results



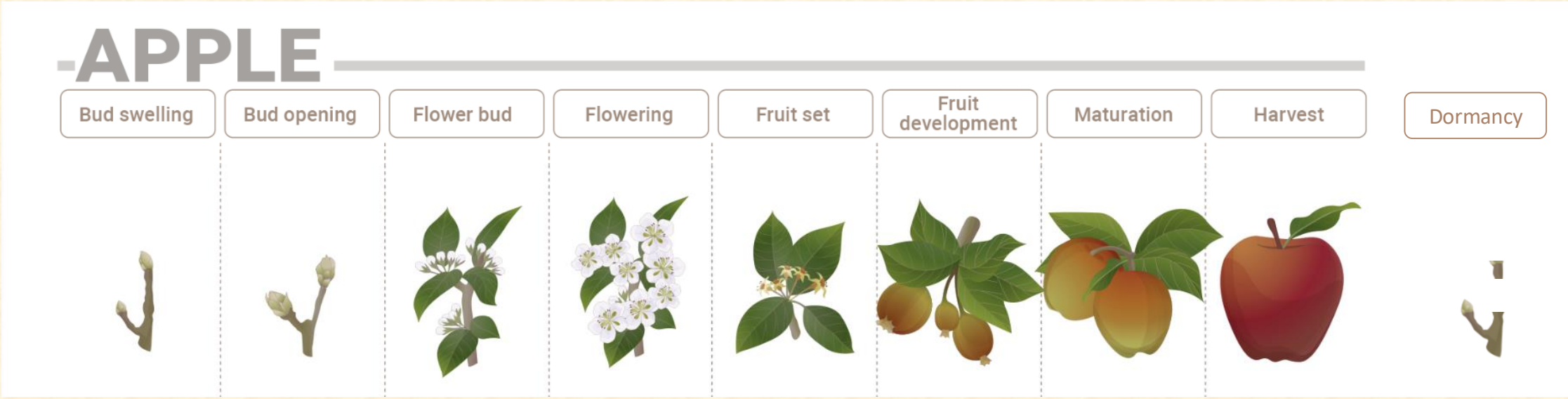
Example: ~2 ft of new growth from 2025 with 65-75 lbs of actual nitrogen applied by apple farmer Stan Devoto (photo credit: Stan Devoto)

Nitrogen

Spring: cover crops disced in

Small N applications if needed

Late autumn: cover crops seeded & compost applied



(Credit: SQM Nutrition)

Potassium

- Leaf K deficiency symptoms look a lot like severe water stress symptoms
- Could be related to low water uptake—could increase irrigation to see if that increases tree K status
- If you have sandy soil, high rainfall, & K deficiency, consider applying K in early spring to avoid leaching

Potassium Deficient Apple

(Credit: Spectrum Analytics, UVM)

Calcium

- See leaf tissue results, visual symptoms
- Soil test results: if you see low Ca and low pH, you could apply lime to help with both
- Calcium sulfate fertilizer (aka gypsum) can add Ca without affecting pH as much

(Credit: Yara)

Zinc

- See leaf tissue results & visual symptoms
- If needed, consider foliar applying zinc (it's not very mobile in the soil), late dormant
- Follow label directions carefully: easy to over apply foliar nutrients & "burn" trees

(Credit: Yara)

Climate-Resilient Water Management

- Access to several sources of irrigation water
- Regular irrigation system maintenance (flushing lines, routine inspections for leaks & clogs, etc.)
- Match irrigation duration & frequency with tree needs
- Phenology-based deficit irrigation
- Dry farming
- Soil health practices (compost, cover crops, etc.)

(Credit: Ellie Andrews)

UC Cooperative Extension
University of California
Agriculture & Natural Resources

Irrigation & Dry Farming – Sonoma County

- Having many different rootstocks & scions in same orchard can create irrigation challenges: different water responses, different needs, drought tolerance
- Most (95%?) of apple orchards here are dry-farmed & do not have irrigation set up, while a small fraction irrigate
- Choose the water management strategies that make sense for your situation, no “one-size-fits all”

(Credit: Ellie Andrews)

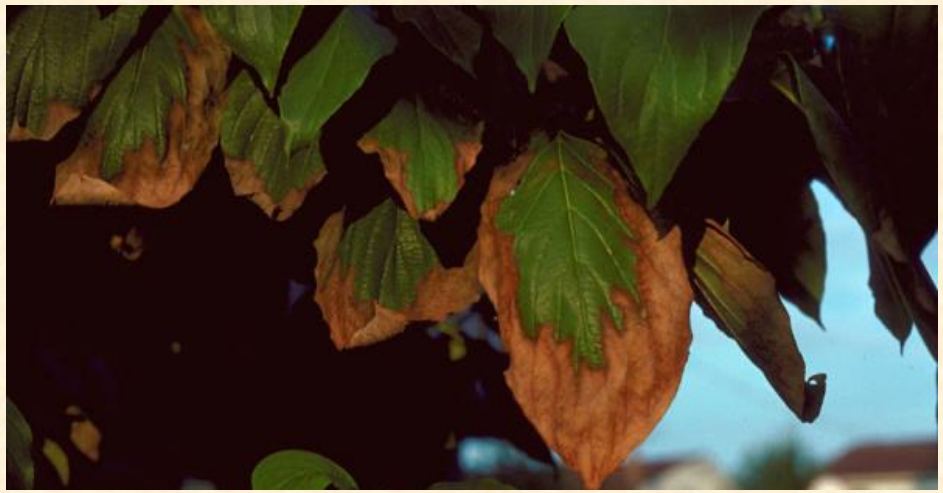
Apple Tree Water Needs

- Regular irrigation supports good growth conditions & healthy fruit trees
- Supply water to prevent severe water stress which can permanently damage trees
- Start by choosing cultivars that have relatively low water requirements that you know you can meet

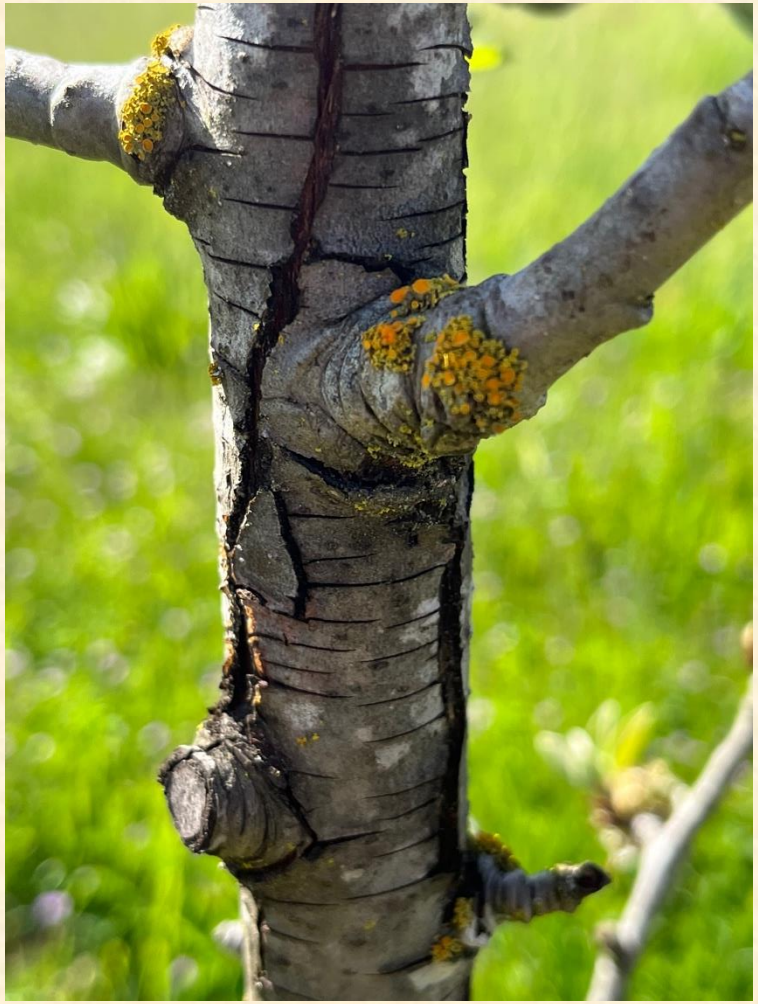
(Credit: Grow Great Fruit)

Water Stress

- Visual symptoms of tree water stress
  - Loss of turgor pressure (wilting)
  - Marginal necrosis (dead leaf tissue)
  - Bark cracking
  - Stunted growth
  - Defoliation
  - Tree death



(Credit: University of Minnesota Extension, Bugwood)



(Credit: Ellie Andrews)

Water Stress

- Water stress can lead to fruit sunburn because of higher fruit temperatures



(Credit: Washington State University)

Water Stress

- Can increase susceptibility to sunburn on branches & trunks too

(UC IPM)

Water Stress

(Credit: Ellie Andrews)

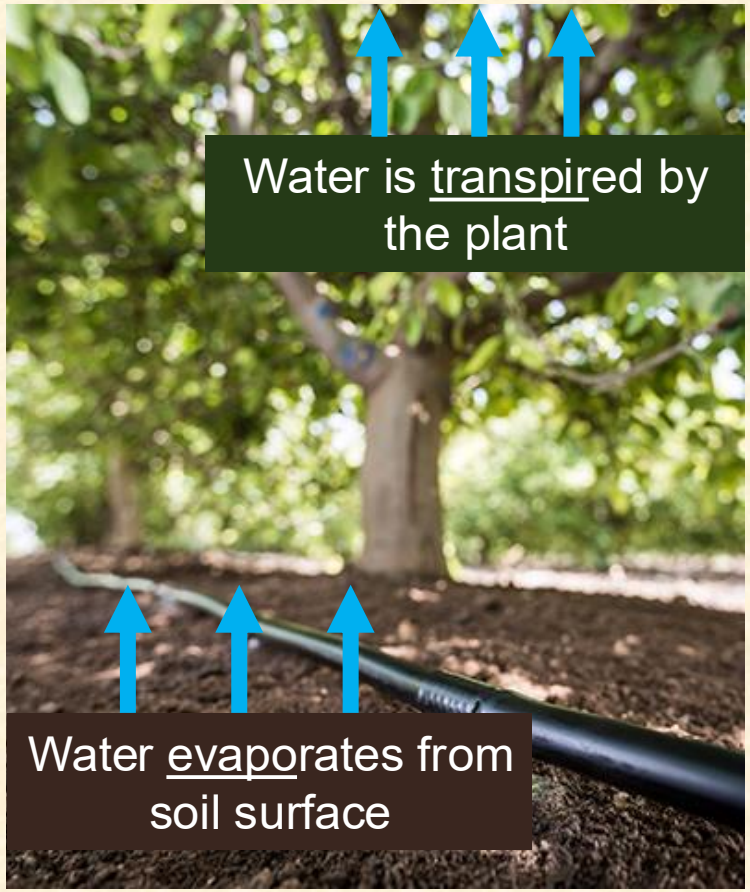
- Rapid cell division happens in early fruit development: receiving enough water then is important for fruit size & quality

- Bear in mind that your goals for fruit size, quality, flavor profile, etc. may differ depending on your end use - fresh vs. cider apples

Water Use

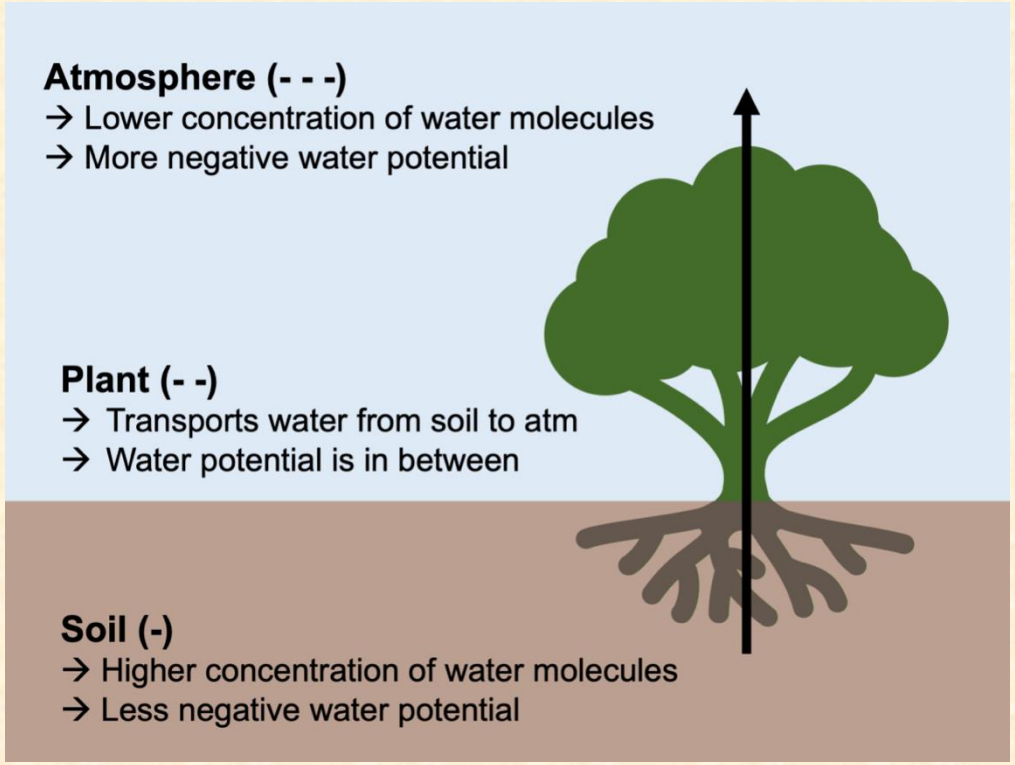
- ET is daily water use
- The amount of water needed depends on:
  - Tree size
  - Tree age
  - Rootstock & scion
  - Tree spacing
  - Soil type
  - Site location
  - Climate (& microclimate)
  - Other environmental factors

Evapotranspiration
water goes to atmosphere



Stem Water Potential

- The most direct way to measure tree water stress
- Answers, “How thirsty are my trees?”
- Collect data at midday or early afternoon
- Compare to established ranges for apples



(Credit: Ellie Andrews)

Stem Water Potential

(Credit: Ellie Andrews)

- Fully irrigated: -6 to -10 bars
- Slightly to moderately water stressed: -10 to -20 bars
- Severely water stressed: -20 bars and lower

Microtensiometers & Dendrometers

- Sensors embedded into trunk, continuously measure tree water tension
- More tension means more water stress
- Less time intensive than pressure chamber, but more expensive

Figure 2. Microtensiometer installed into the trunk of the tree, real (A) and scheme (B).

(Blanco et al. 2022 WSU Tree Fruit)

Soil Moisture Monitoring Tools

- Soil Water Content: the current status of the amount of water in the soil
- There are many different soil moisture probe options

Water Mark Sensor (~$45)

Sensor Reader (~$250)

Tensiometers (~$100)

(Products are mentioned as examples, not endorsements.)

Phenology-Based Deficit Irrigation

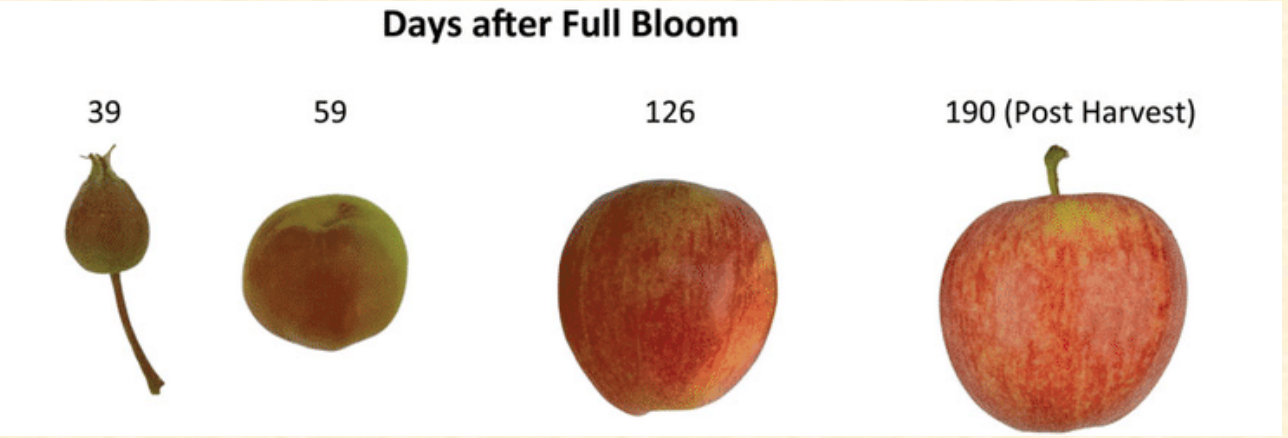
- Goal: match the timing of water deficit with the timing of crop water stress tolerance
- Apply water during periods of critical plant growth & development, but not during water stress sensitive stages
- Reduce water use during periods of plant growth when crops have lower sensitivity

(Credit: Ellie Andrews)

Phenology-Based Deficit Irrigation

- Bearing trees can tolerate some moderate water stress until the fruit is ~1/2 size
- Then irrigation can help increase fruit size

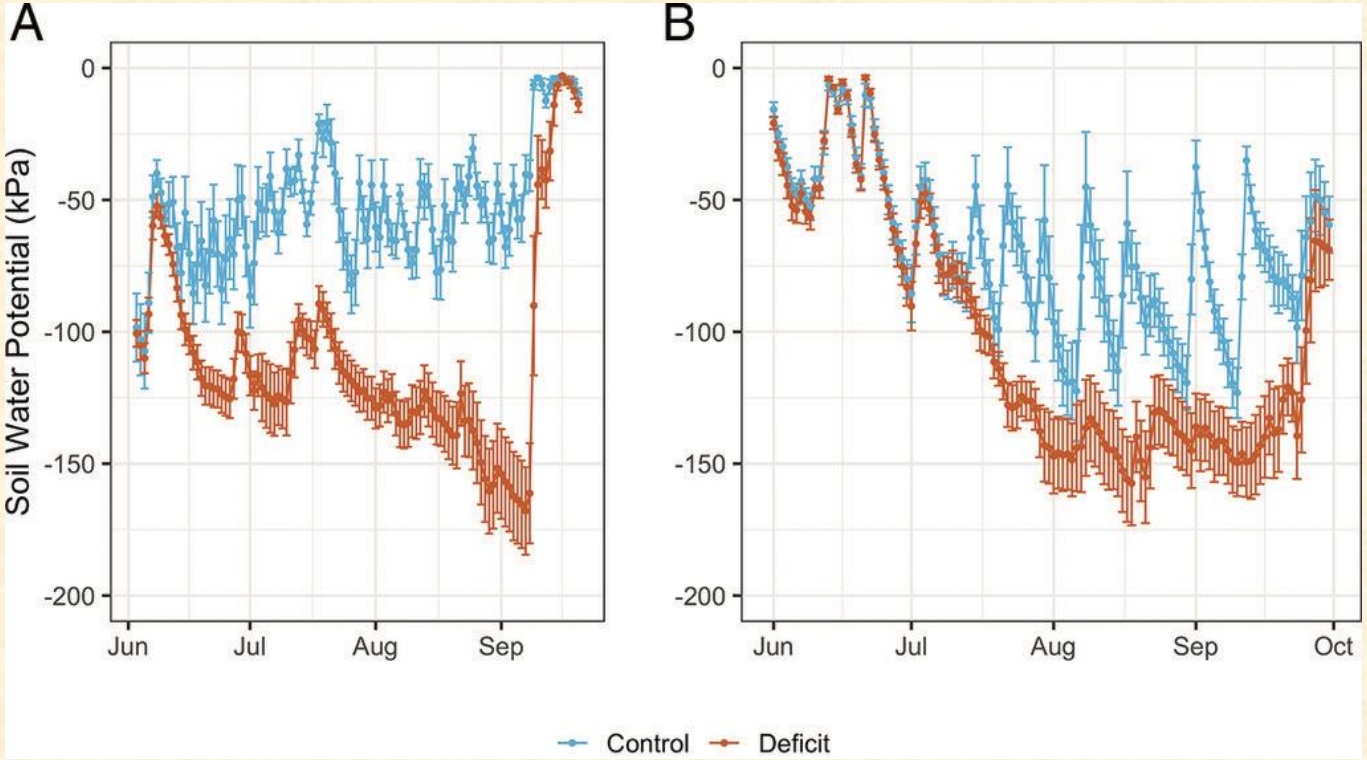
- Moderate water stress during later fruit development can increase fruit quality (Wang et al. 2019)
  - Fructose, glucose, sorbitol content



(Henry-Kirk et al. 2018)

Phenology-Based Deficit Irrigation

- Regulated deficit irrigation can reduce fruit size & increase fruit polyphenolic compounds, total soluble solids, firmness, & titratable acidity (Kendall et al. 2021)
- Neutral or positive impacts for cider quality



(Kendall et al. 2021)

What is Dry Farming?

- Unirrigated crop production *during the dry season*
- Usually in regions receiving 20+ inches of annual rainfall with a warm summer Mediterranean climate
- Soil moisture from the rainy season is captured & stored in the soil & used by crops later during the dry season
- Growers can use strategies that make it easier for crops to use that water in the summer

(Hale's Apple Orchard, credit: Ellie Andrews)

Benefits of Dry Farming

- Water savings: reduced irrigation use & costs
- Increased productivity on land with low/no water access
- Mitigating drought-related risks, offers some crop security during times of uncertain water supply
- Reduced weed pressure
- Improved yield quality
- New marketing potential due to quality improvements & water conservation

(Credit: Ellie Andrews)

Limitations of Dry Farming

- Yield quantity tends to be lower than irrigated orchards: important to set realistic expectations
- May require wider plant spacing
- Some winters, it might not rain at all which can lead to more severe water stress the following season, compromised tree health & longevity

(Credit: Ellie Andrews)

“Dust Mulching” aka Surface Tillage

(Hale’s Apple Orchard,
credit: Ellie Andrews)

- Some growers use surface tillage to seal in soil moisture by breaking capillary action
- Benefits: moisture retention deeper in soil profile
- Tradeoffs: erosion risk, over time reduces SOM
- May be more suitable in some locations than others

Dry Farming Strategies

- Rootstock & scion selection: water efficient, drought tolerant, early maturing, deep roots
- Improve soil structure for good infiltration
- Widen tree spacing to maximize water use

(Credit: Ellie Andrews)

Dry Farming – It's not All-or-Nothing

(Credit: Ellie Andrews)

- Consider trying it out first on a small area & hone your approach before scaling up
- Some areas of your orchard may be better suited than others
- Consider deep-irrigating crops at planting to help them get established
- You can irrigate crops at key times throughout the dry season if needed especially when you're beginning to experiment with dry farming

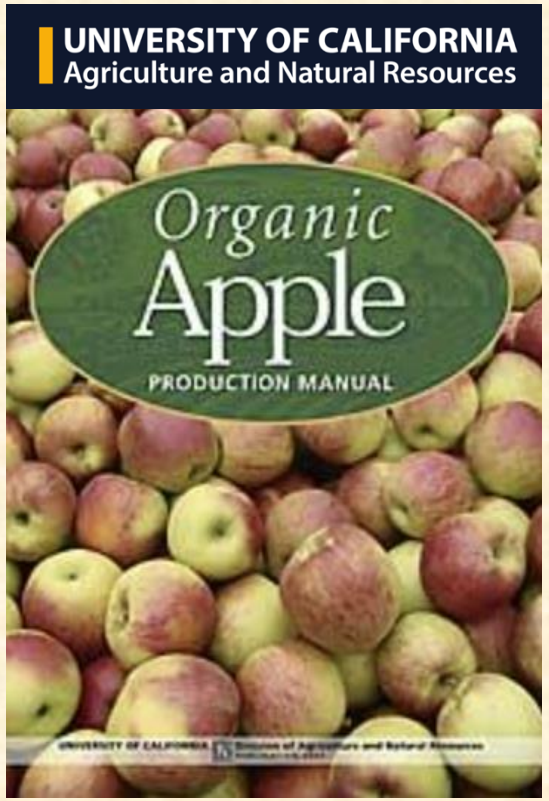
Dry Farming Resources

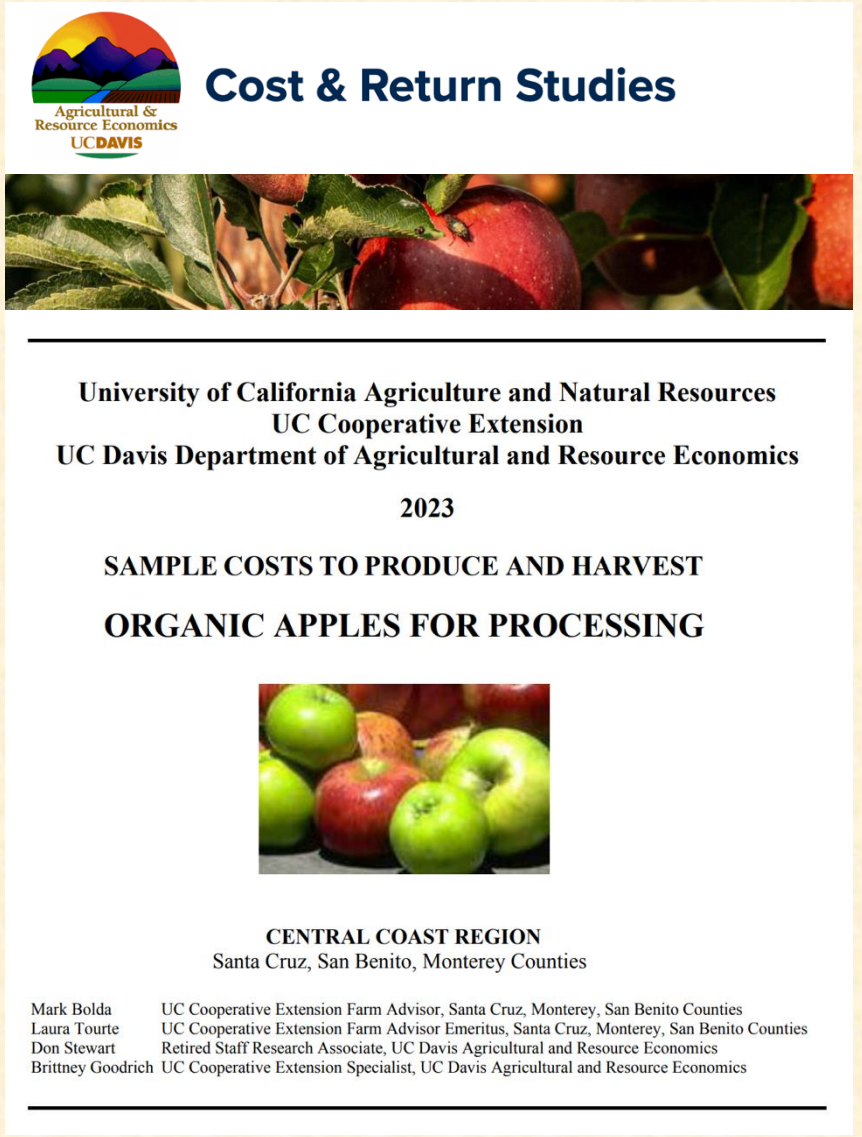
- OSU Dry Farming Institute's annual virtual convening on dry farming in February, recordings of all past events are on their website
- OSU Dry Farming Accelerator Program: a self-paced course

UC Cooperative Extension
University of California
Agriculture & Natural Resources

UC Apple Production Resources

- UC ANR Manuals
- UC Davis Cost Studies





Thank you!

UC Cooperative Extension
University of California
Agriculture & Natural Resources

Visuals

- Boron (B) deficiency symptoms
  - Chlorosis starting in new leaves
  - Scorched margins that roll inward
  - Terminal bud dieoff
  - Corky spots on lateral shoots
  - Symptoms show up on fruit early in development

Credit: Yara

Visuals

- Boron (B) deficiency symptoms
  - Reduced fruit size
  - Deformed, dimpled, cracked fruit with corking
  - Can be confused with Ca deficiency, but B deficiency symptoms start earlier in fruit development than Ca deficiencies

Credit: Yara

Credit: Eric Hanson, MSU

Diagnostics

- Magnesium (Mg) deficiency symptoms
  - Start in older leaves first
  - Interveinal chlorosis (yellow tissue) & necrosis (dead tissue)
  - Early fruit drop

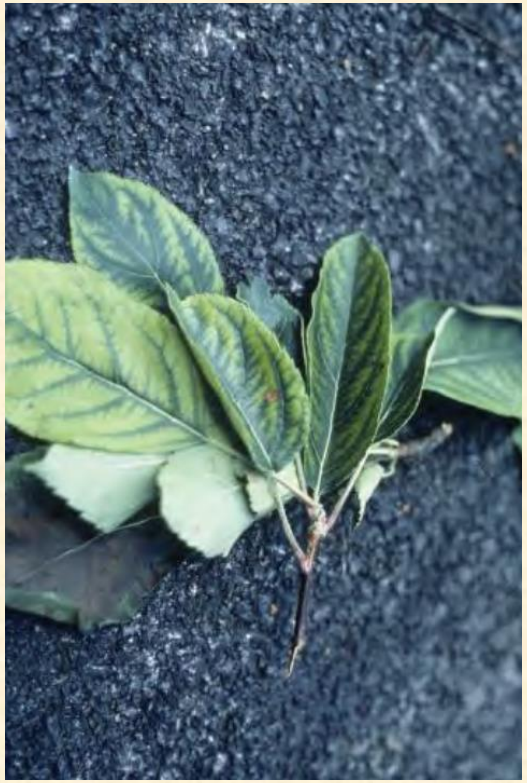
Credit: Eric Hanson, MSU

Credit: Yara

Diagnostics

- Manganese (Mn) deficiency symptoms
  - More common on alkaline soils & during dry seasons
  - Similar symptoms as Mg deficiency by appear first on young leaves
  - Interveinal chlorosis while main vein remains green

Credit: Eric Hanson, MSU



Credit: Yara

Diagnostics

- Manganese (Mn) toxicity symptoms
  - More common where pH <5.5 in young trees, Red Delicious is very susceptible
  - Cambium tissue under bark dies on young twigs causing cracked bark aka “measles”

Credit: Eric Hanson, MSU

Diagnostics

- Iron (Fe) deficiency symptoms
  - Symptoms start on young leaves
  - Begins with pale chlorosis
  - Then can become lemon yellow, pale yellow, whitish or bleached interveinal chlorosis over time
  - Main veins stay green
  - Can cause necrotic margins

Credit: Yara

Credit: Eric Hanson, MSU

Example

- An apple grower near Sebastopol noticed leaf discoloration, canopy dieback & defoliation
- They sent leaf samples in to a lab to compare 4 symptomatic trees with 1 healthy tree
- All symptomatic trees were severely deficient in nitrogen & potassium, while the healthy tree had only mild deficiencies
- The grower is amending the soil to provide more organic nutrient inputs (kudos to them!)