Friend or Foe?
Vine Nutrition Effects on Grape and Wine Quality
Location, location...

- Water and nutrients limit vine productivity
- Climate variation and change
- Amount and frequency of rainfall
- Evaporation (temperature)
- Spatial variation
- Soil water/nutrient holding capacity
  - Soil texture (loam/sand)
  - Rooting depth
  - Organic matter
  - pH
- Vine age/size
Ground rules

2 - 6 lbs N/ton
Nutrient availability and uptake

- Nutrients concentrated in surface soil
- Availability linked to soil water
- Large spatial/temporal variation
  → Roots grow in nutrient-rich zones
- Different nutrients in different locations
  (leaching: $\text{NO}_3^-> > \text{K}^+ > > \text{H}_2\text{PO}_4^-$)
  → Shallow roots: immobile nutrients
  → Deep roots: mobile nutrients
- Active uptake → Concentration
- Transpiration $\Rightarrow$ → Uptake $\Rightarrow$
Nitrogen: What is it?

Chemical component of:

• Nucleic acids → DNA → Genes
• Amino acids → Proteins → Enzymes
• Chlorophyll → Light interception
• Hormones → Communication
• Secondary metabolites → Color, flavor
Nitrogen uptake and processing

• N₂ in atmosphere (80%) useless for grapevines
• Mostly nitrate (NO₃⁻) dissolved in soil water
• Soil water [NO₃⁻] << Tissue [NO₃⁻]
• Active uptake via H⁺-ATP pump and H⁺/NO₃⁻ cotransport
• Uptake requires B (for ATP pump)
• Assimilation requires Mg²⁺, Mn²⁺ or Co²⁺ (as GS cofactors) and carbohydrates → Expensive!
• Transport (xylem), storage (vacuole), or assimilation → Amino acids → Proteins
N uptake and assimilation

SOIL SOLUTION

NO$_3^-$ $\rightarrow$ NH$_4^+$ $\rightarrow$ Amino acids $\leftrightarrow$ Proteins

LEAVES and FRUIT

NO$_3^-$ $\rightarrow$ NH$_4^+$ $\rightarrow$ Amino acids $\leftrightarrow$ Proteins

XYLEM

NO$_3^-$ Amino acids

PHLOEM

Sucrose Amino acids

ROOTS

NO$_3^-$ $\rightarrow$ NH$_4^+$ $\rightarrow$ Amino acids $\leftrightarrow$ Proteins

SOIL SOLUTION

NO$_3^-$ NH$_4^+$
Roots pass surplus on to shoots
Growth and nutrient status

- Growth drives nutrient uptake
- Insufficient nutrient supply → growth
- Water deficit → mass flow + mineralization → nutrient availability
- Water deficit → growth → nutrient demand
- Nutrient deficiency → - cell division
  - root:shoot ratio
  - leaf starch
  - photosynthesis
  - root transport system
  - reserve remobilization

Bloom
Vine N demand
Soil N supply
Veraison
Harvest
Leaf fall
N Deficit

- Root growth
  → Drought susceptibility
- Shoot growth
- Photosynthesis
  → Energy overload
  → Chlorophyll
  → Carbohydrates
  → Anthocyanins
- Leaf senescence
  → Nutrient recycling
K Deficit

- Root growth (↗) (K → cell expansion)
- Shoot growth ↘
- Photosynthesis ↘
- Sugar export (phloem flow) ↘
  → Ripening, reserves ↘
- Berry ‘shrivel’ (?)
- Xylem sap flow ↘
- Leaf senescence
  → Nutrient recycling
P Deficit

- Root growth \( \uparrow \) (shallow), \( \downarrow \) (deep) → Drought susceptibility \( \uparrow \)
- Mycorrhiza → P supply \( \uparrow \)
- Shoot growth \( \uparrow \uparrow \) (laterals) → Carbohydrates \( \uparrow \)
- Photosynthesis \( \uparrow \)
  → Energy overload
  → Anthocyanins \( \uparrow \)
- Mg transport in xylem \( \uparrow \)
  → Mg deficiency symptoms
- Leaf senescence
  → Nutrient recycling
Use but beware of competition!
Stress and yield

- Vegetative growth vs. reproductive growth
- Time of nutrient deficit important
  - Budbreak – bloom
  - Bloom – fruit set
  - Cell division – cell expansion
  - Pre-veraison – post-veraison

→ The later a stress occurs, the smaller its effect on yield
Early stress → Poor fruit set

• N, K, P, Ca, Fe, B, Zn, Cu, Mo,…, and salinity
• Often ‘hens & chicks’ (especially Zn, Mo, B)
• Nutrient stress also exacerbates water stress

N deficit? Yes No

![Graph showing the relationship between Total xylem N (mM) and Fruit set (%) with regression line and correlation coefficient r = 0.58, p < 0.001]
How much N to apply?

...it depends!

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...it depends!
N and fruit quality

- **RDN** (Regulated Deficit Nutrition):
  - Berry size (unless fruit set)
  - Sugar
  - Malate (less production)
  - Tartrate
  - K⁺
  - pH
  - Amino acids (arginine!)
  - Phenolics (anthocyanins, flavonols...)
  - Flavors

- Post-veraison berries remain responsive to N
N: Moderation is a virtue

- More N → Higher yield
- More N → More lateral shoot growth, denser canopy
- Growing shoot tips compete with fruit → Delayed ripening
- N suppresses secondary metabolism (phenolics)
- N (and S) enhances volatile thiol precursor production
How to get poor color

- Increasing N at bloom
- Decreasing light at veraison

Anthocyanins (mg/g skin fw)

Weeks after veraison

N1 N5 N10
100%
20%
2%

Decreasing light at veraison

Worst case: High bloom-N + clouds during ripening
Not possible to solve high-N problems with hedging
Exposure: Too much of a good thing?

Low N
Morning sun

High N
Afternoon sun

N suppresses flavonol production
• Food for **yeast**: More N needed with water deficit
• Post-harvest N only with long post-harvest period
• Veraison N as good as bloom N for YAN
The Whites vs. the Reds

- Berry size and sun exposure less important for white grapes (phenolics $\rightarrow$ astringency, bitterness!)
- Moderate N supply maximizes aroma potential
  $\rightarrow$ Precursors of volatile thiols (mercaptans)
  $\rightarrow$ ‘Blackcurrant’, ‘passion fruit’, ‘grapefruit’, (‘skunk’!)
- Low N $\rightarrow$ Low YAN (<150 mg/L) $\rightarrow$ Sluggish/stuck fermentation $\rightarrow$ H$_2$S (‘rotten eggs’!)
- More N may delay ripening
  $\rightarrow$ Acid/flavor retention (advantage in hot seasons)
High N $\rightarrow$ Disease susceptibility

- Berries per cluster
- Berry weight (g)
- Soil N (g/vine)
- Botrytized
- Healthy
- Soil N
- Chardonnay
- Cabernet S.
- Powdery mildew severity (lesions/leaf)
- High N $\rightarrow$ Disease susceptibility
**Botrytis: What is the problem?**

- *Botrytis* destroys berry cell integrity (membrane rupture) → Mixing of cell components
- *Botrytis* secretes laccase = ‘nasty’ form of PPO (stable at low pH, high temperature (>120°F), ethanol) → Oxidizes phenolics (hydroxycinnamates, anthocyanins, tannins)
- Oxidation products (quinones) oxidize other compounds (ascorbate, SO₂)
- Worse in grapes with high hydroxycinnamate and low glutathione (S transport & storage form) contents → Control *Botrytis*, avoid mechanical damage, N and S deficiency or excess, (late) overexposure!
K: The pH conundrum

- Juice and wine pH is sensitive to K
- Juice pH is not very responsive to soil K (→ More malate)
- High soil pH may lead to lower juice pH (→ Ca)

![Graph showing the relationship between Juice K+ (g/L) and Juice pH for Merlot, Syrah, and Chardonnay varieties.](image)
When to apply nutrients?

- **Phase 1**
  - Bloom

- **Phase 2**
  - Lateral shoots
  - Primary shoots
  - Fruit
  - Roots

Growing season:
- Jan
- Feb
- Mar
- Apr
- May
- Jun
- Jul
- Aug
- Sep
- Oct
- Nov

Growth
The good news: It’s in the book!