WASHINGTON STATE UNIVERSITY

World Class. Face to Face.

Friend or Foe? Vine Nutrition Effects on Grape and Wine Quality

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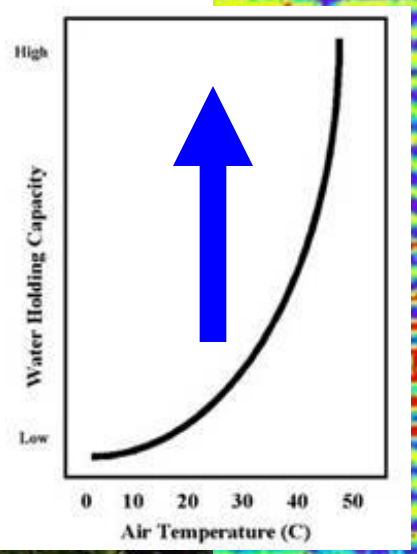
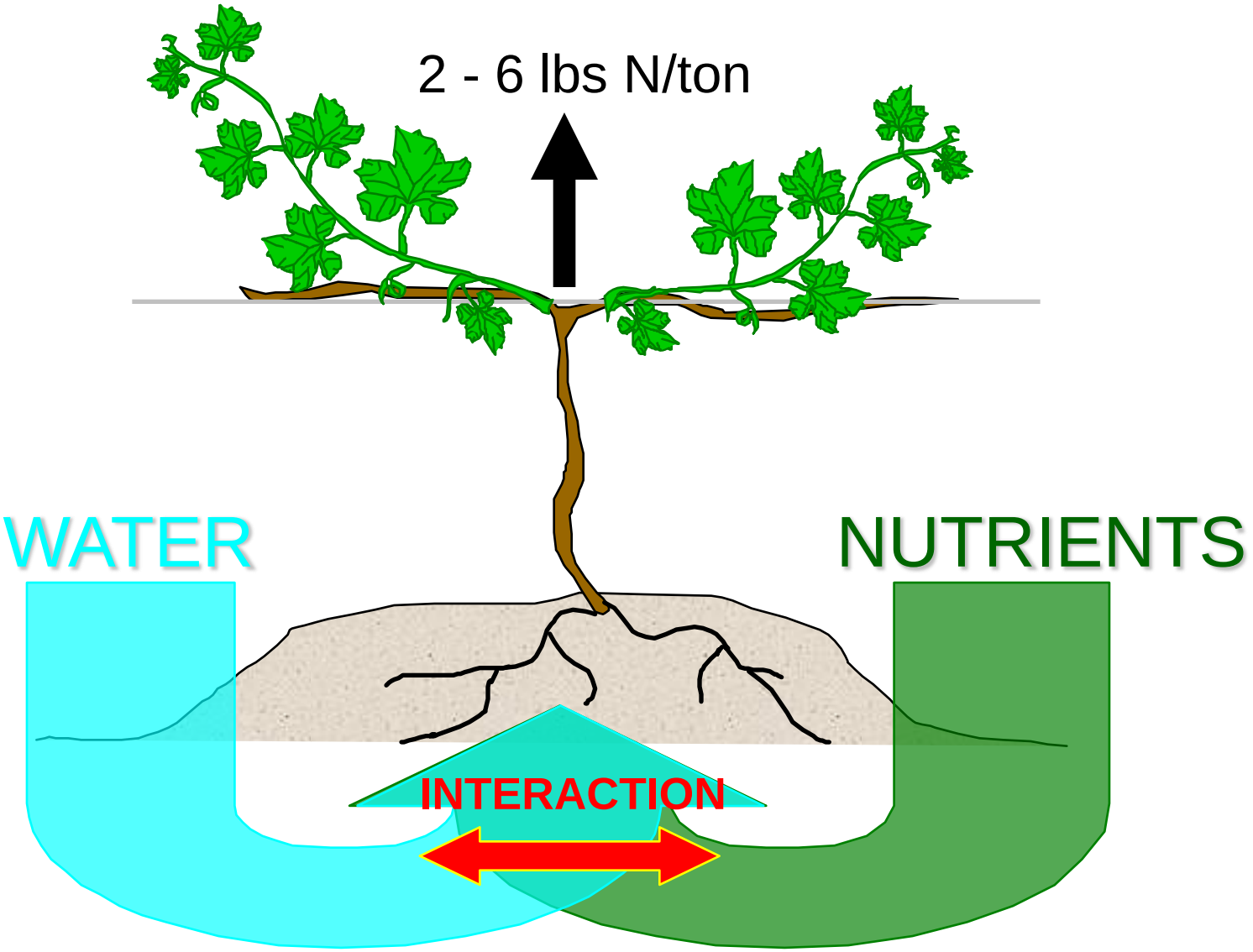
Location, location…

- 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



Nutrient availability and uptake

- Nutrients concentrated in surface soil
- Availability linked to soil water
- Large spatial/temporal variation
  $\rightarrow$ Roots grow in nutrient-rich zones
- Different nutrients in different locations
  (leaching: NO_3^- >> K^+ >> $H_2PO_4^-$)
  $\rightarrow$ Shallow roots: immobile nutrients
  $\rightarrow$ Deep roots: mobile nutrients
- Active uptake $\rightarrow$ Concentration
- Transpiration $\nearrow \rightarrow$ Uptake $\nearrow$

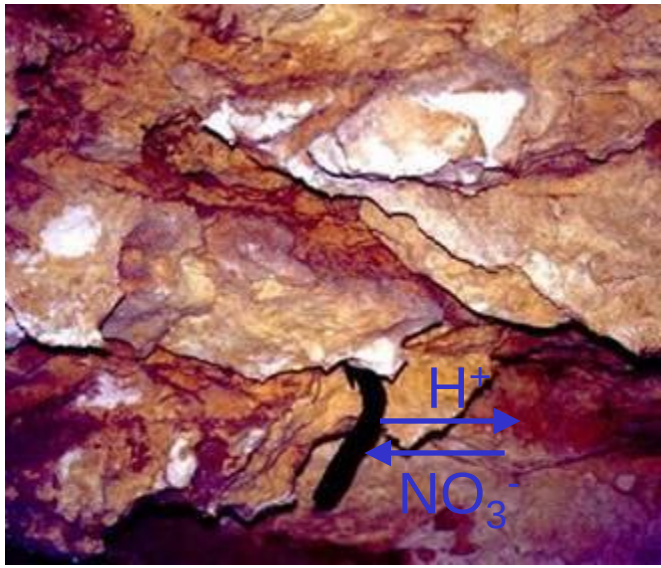
Nitrogen: What is it?

Chemical component of:

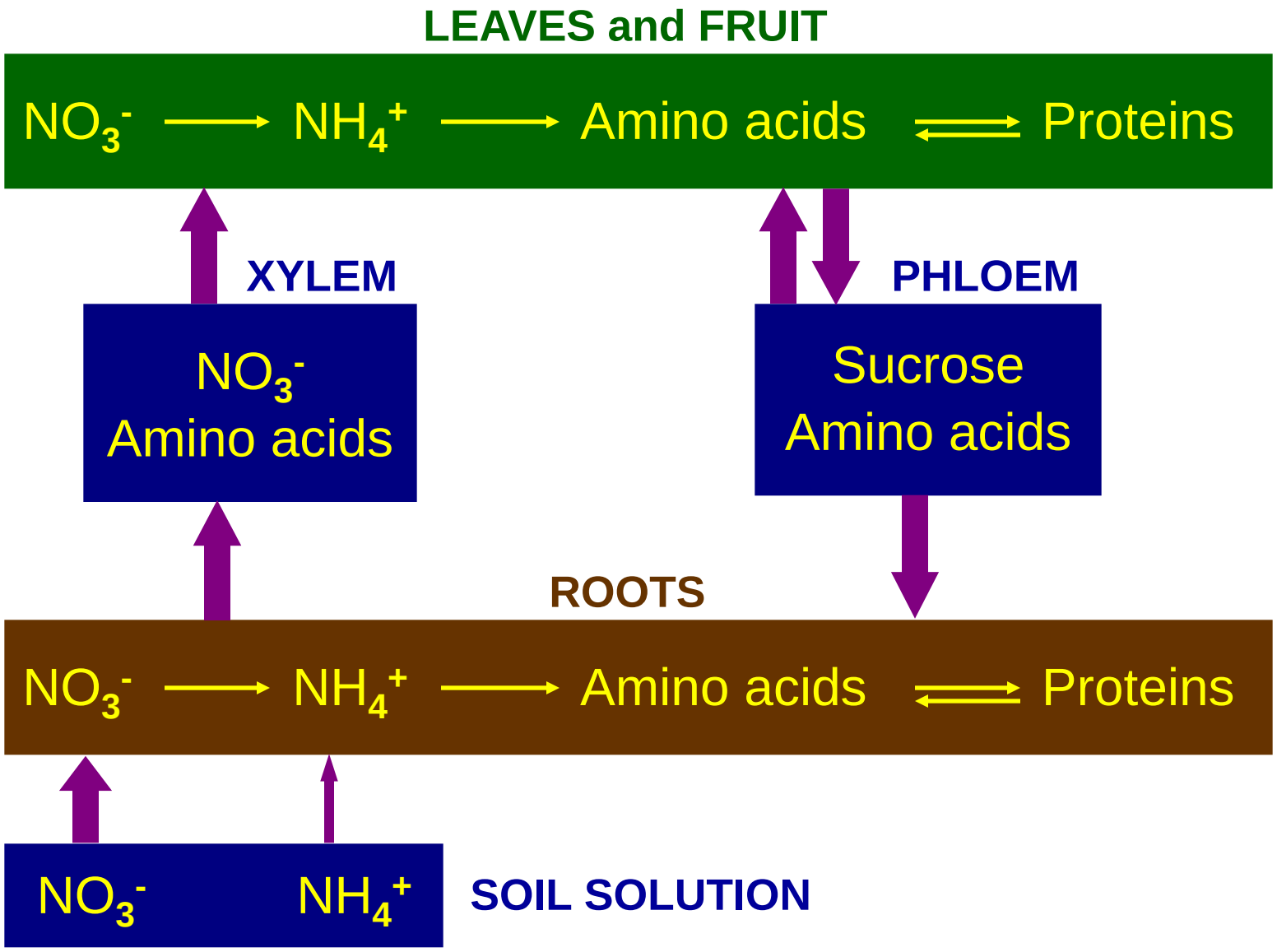
- Nucleic acids → DNA → Genes
- Amino acids → Proteins → Enzymes
- Chlorophyll → Light interception
- Hormones → Communication
- Secondary metabolites → Color, flavor

Nitrogen uptake and processing

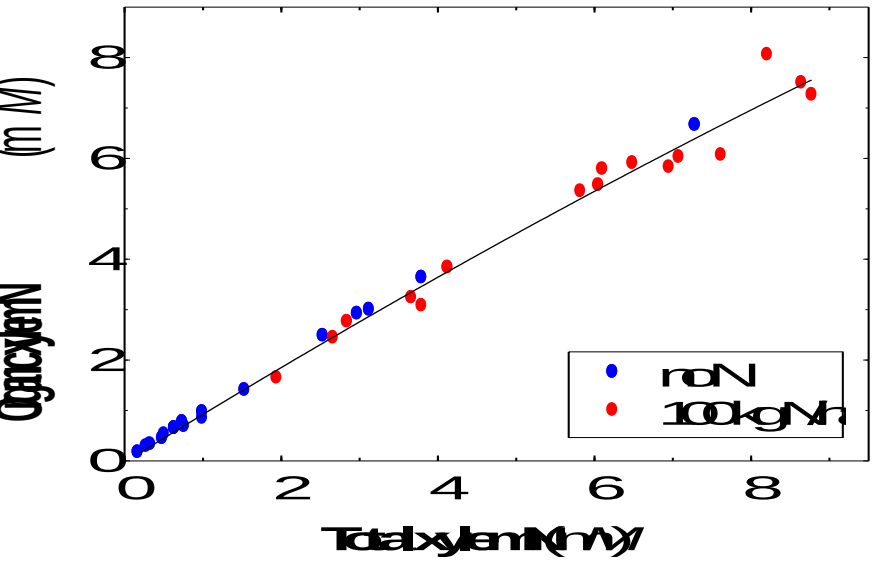
- N_2 in atmosphere (80%) useless for grapevines
- Mostly nitrate (**NO_3^-**) dissolved in soil water
- Soil water [NO_3^-] << Tissue [NO_3^-]
- Active uptake via H^+-ATP pump and H^+/NO_3^- cotransport
- Uptake requires **B** (for ATP pump)
- Assimilation requires **Mg^{2+}**, **Mn^{2+}** or **Co^{2+}** (as GS cofactors) and carbohydrates → Expensive!
- Transport (xylem), storage (vacuole), or assimilation → Amino acids → Proteins

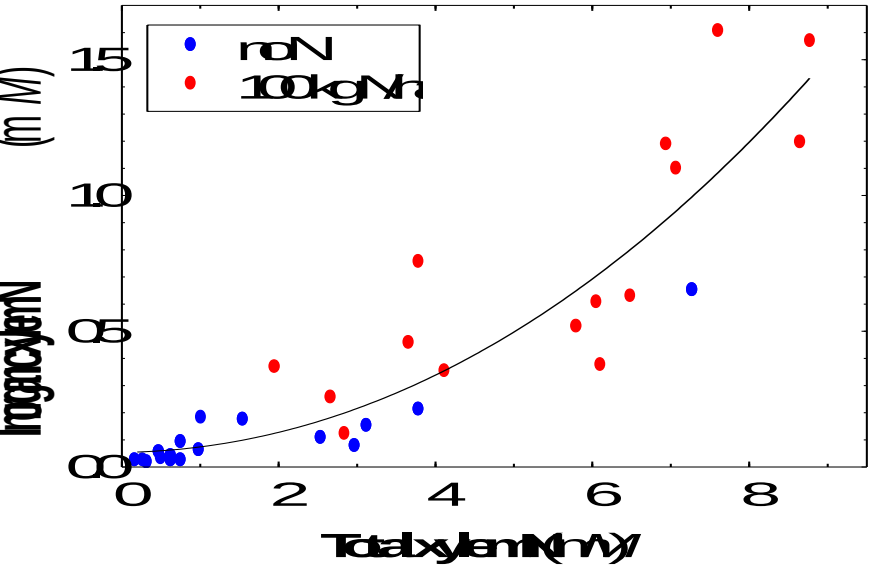


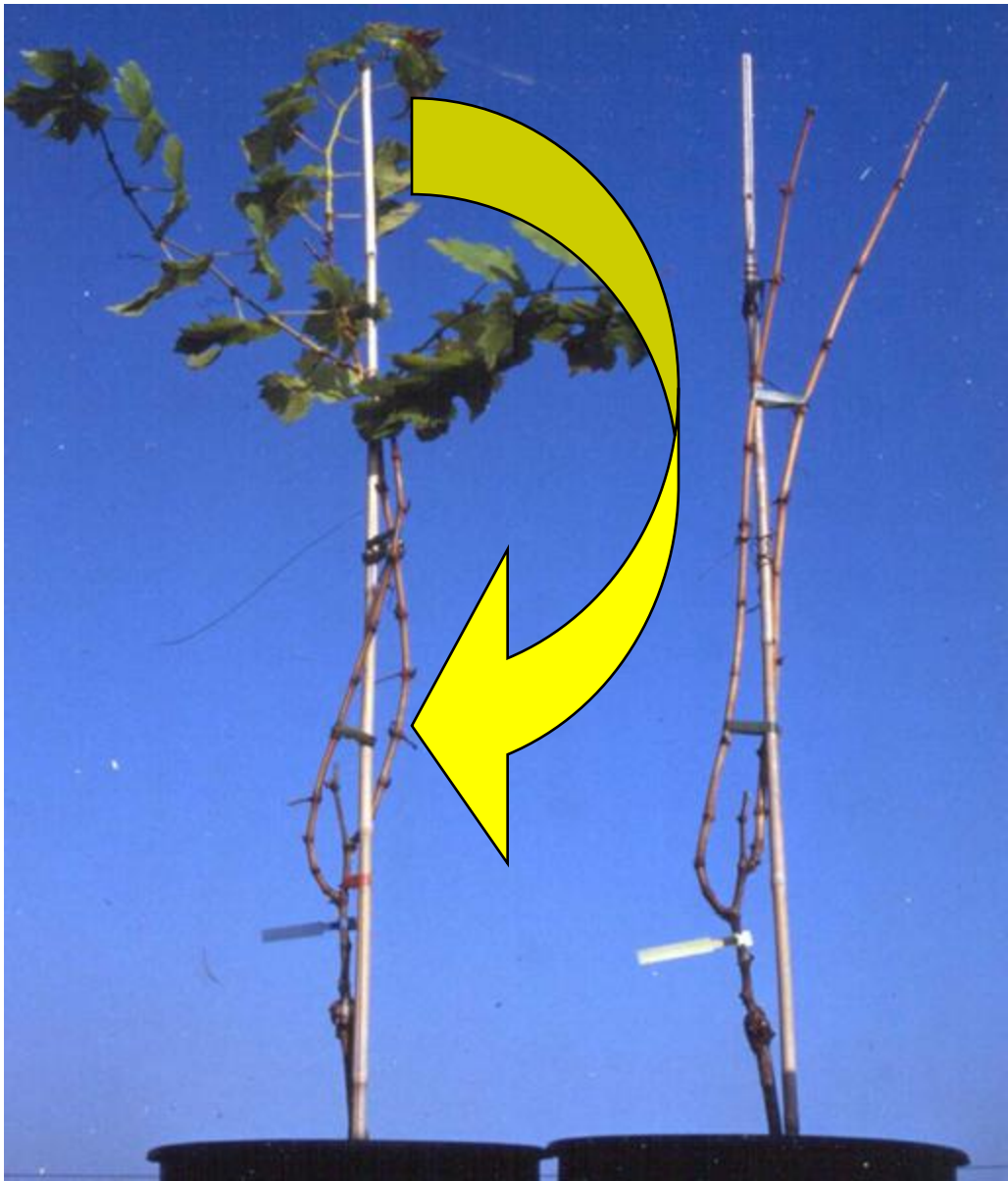
N uptake and assimilation



Roots pass surplus on to shoots

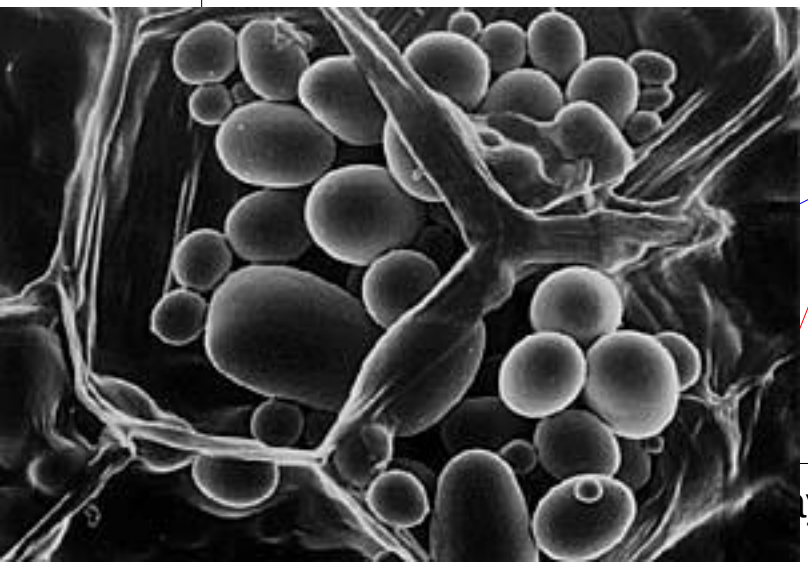


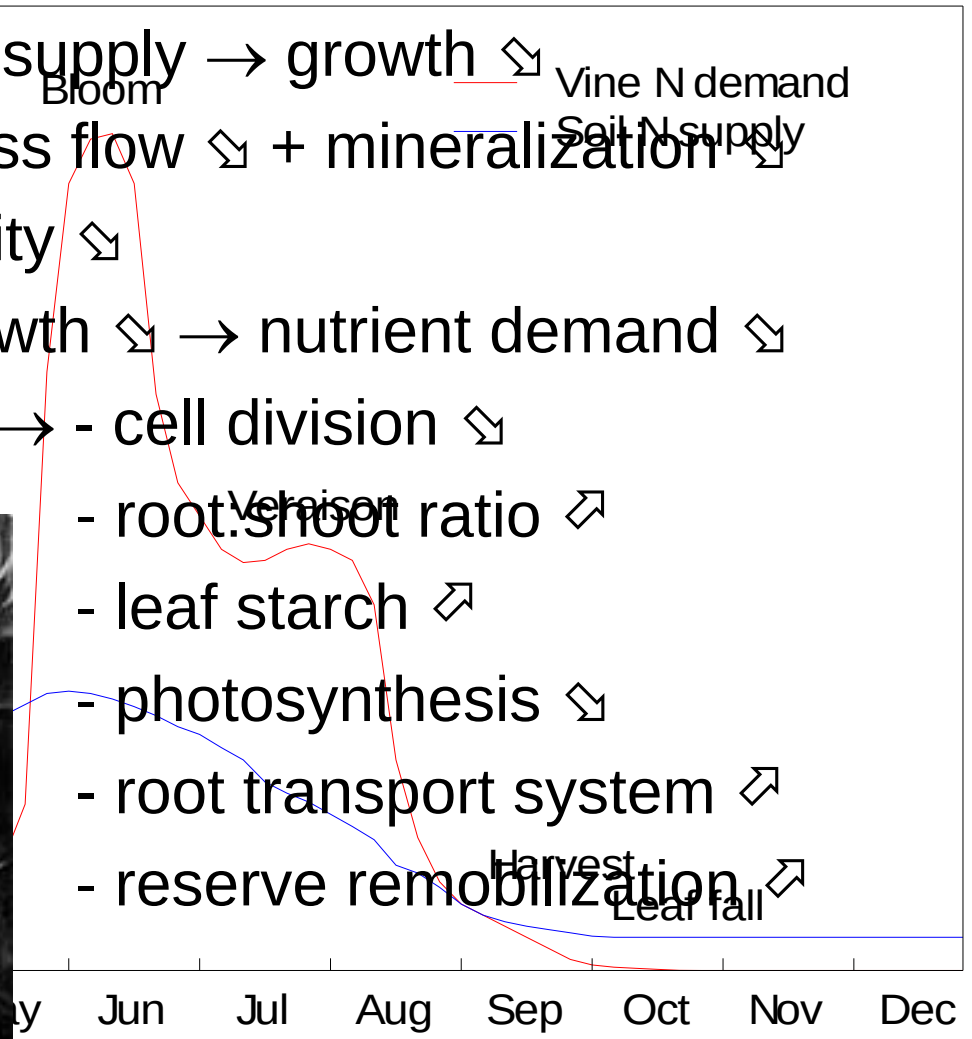


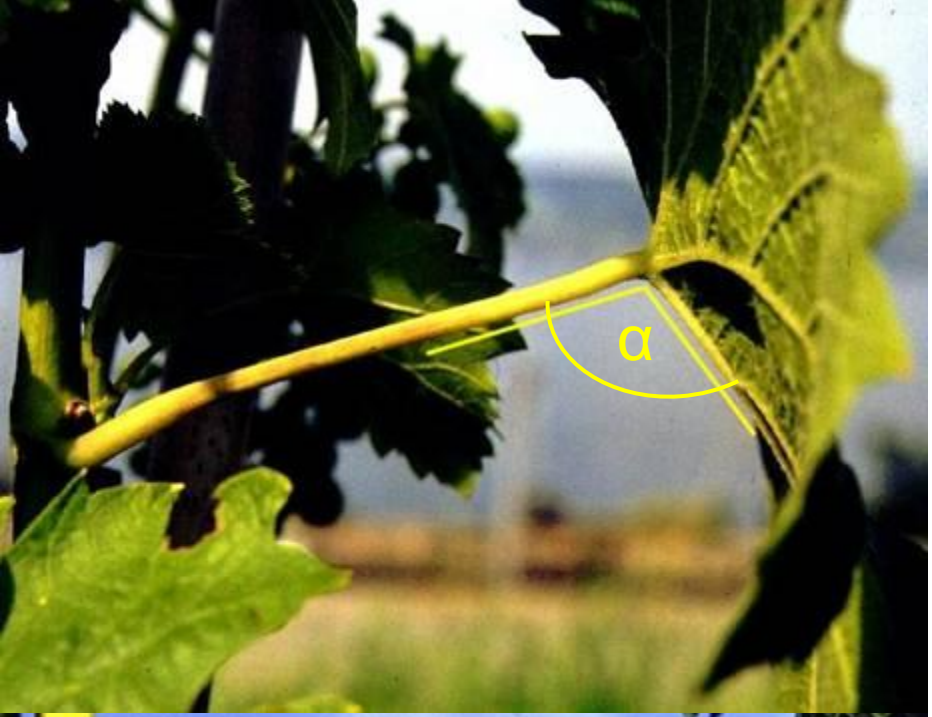


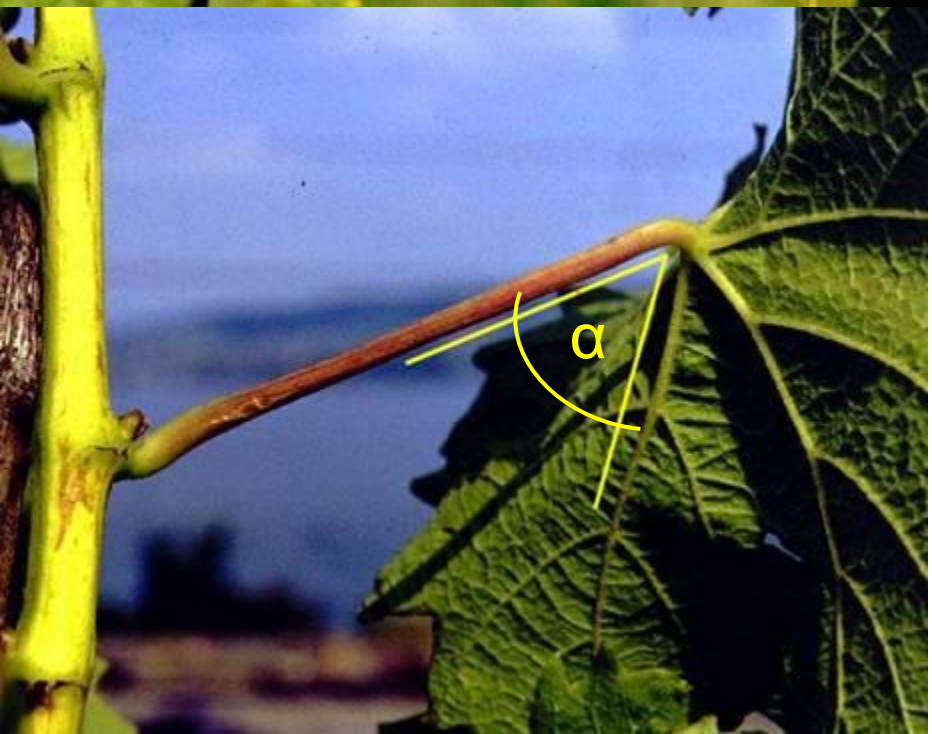
Growth and nutrient status

- 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 ↗





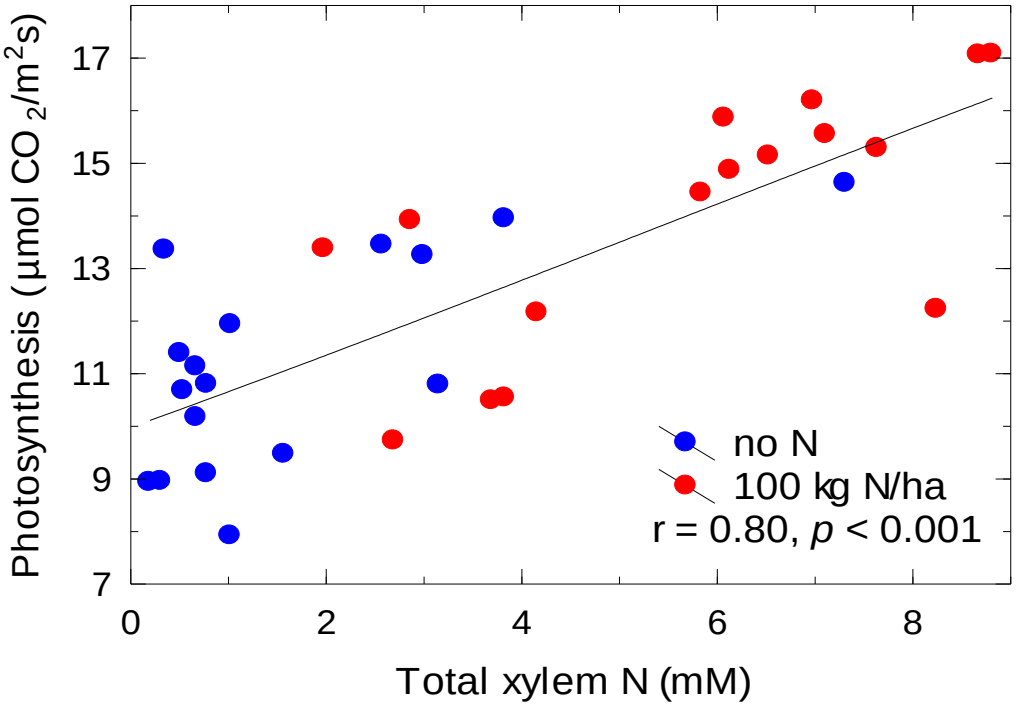


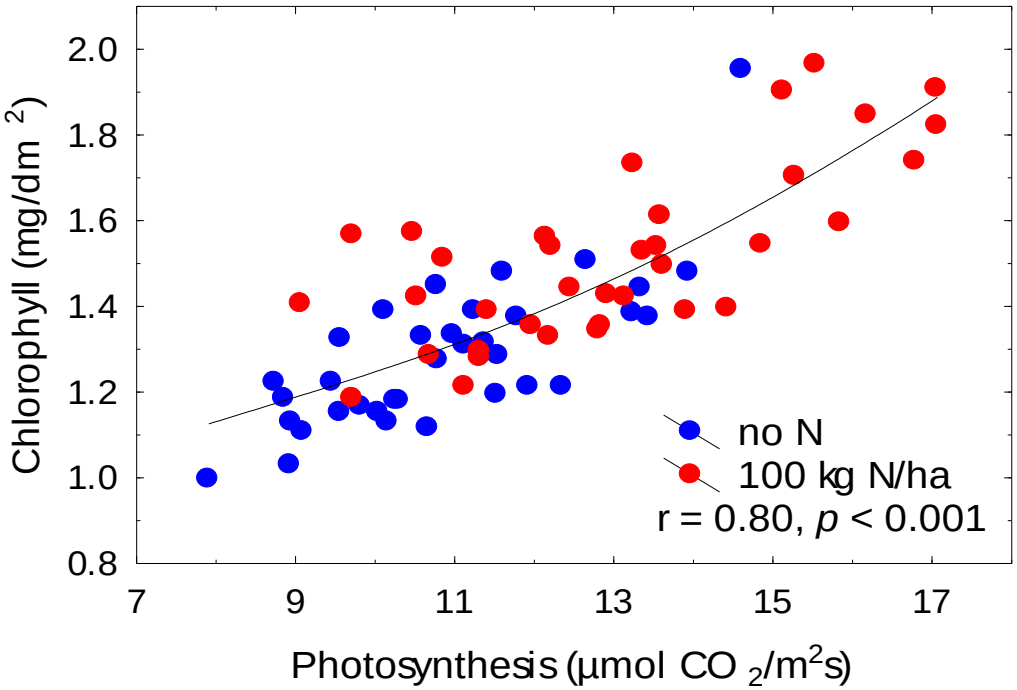


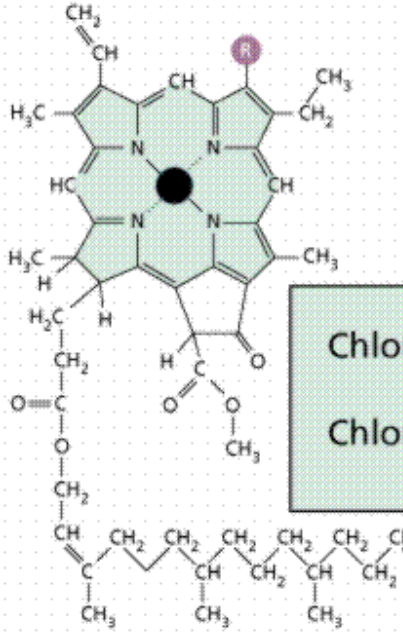
N Deficit

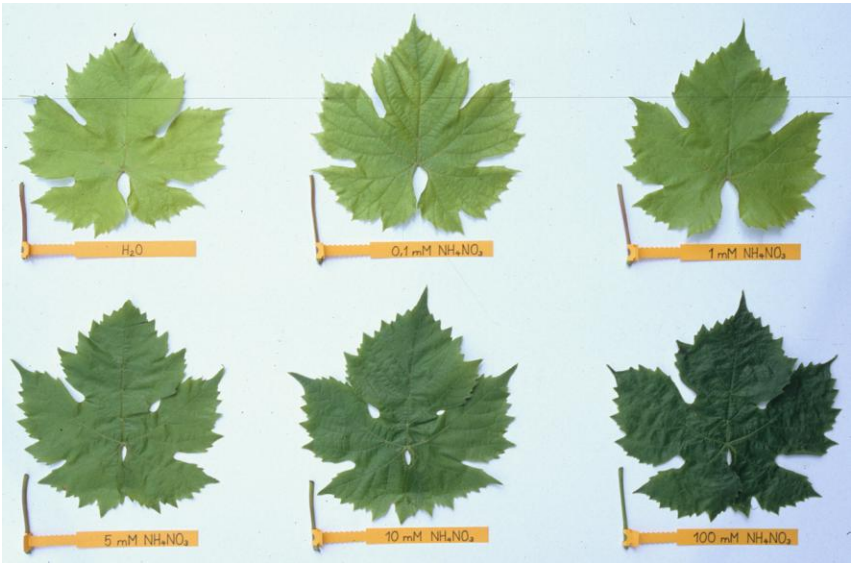
- Root growth ⇗
  → Drought susceptibility ⇘
- Shoot growth ⇘⇘
- Photosynthesis ⇘
  → Energy overload
  → Chlorophyll ⇘
  → Carbohydrates ⇗
  → Anthocyanins ⇗
- Leaf senescence
  → Nutrient recycling

Photosynthesis







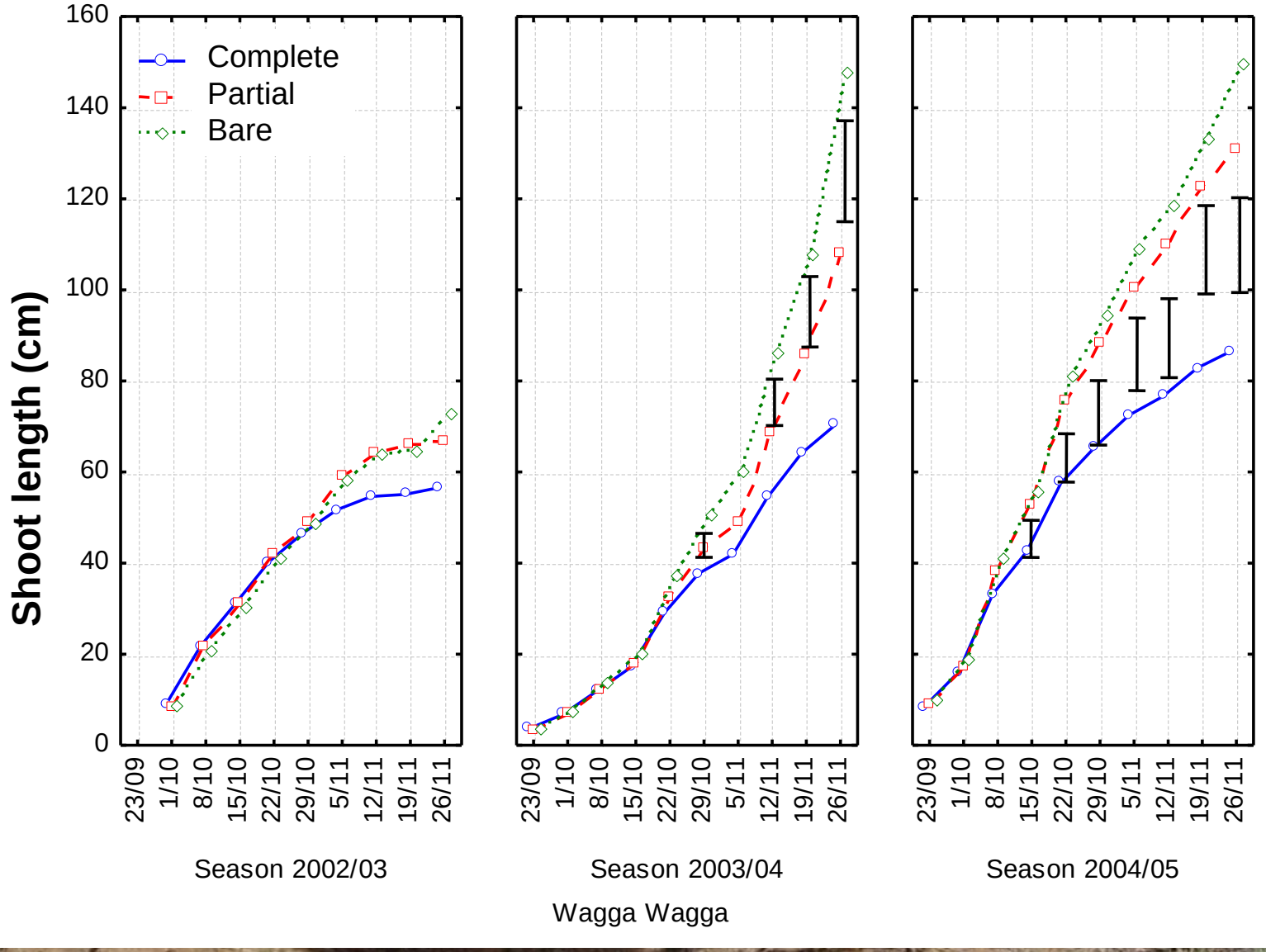


K Deficit

- 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 ⇗ (shallow), ⇘ (deep)
  → Drought susceptibility ⇗
- Mycorrhiza → P supply ⇗
- Shoot growth ⇘⇘ (laterals)
  → Carbohydrates ⇗
- Photosynthesis ⇘
  → Energy overload
  → Anthocyanins ⇗
- Mg transport in xylem ⇘
  → Mg deficiency symptoms
- Leaf senescence
  → Nutrient recycling

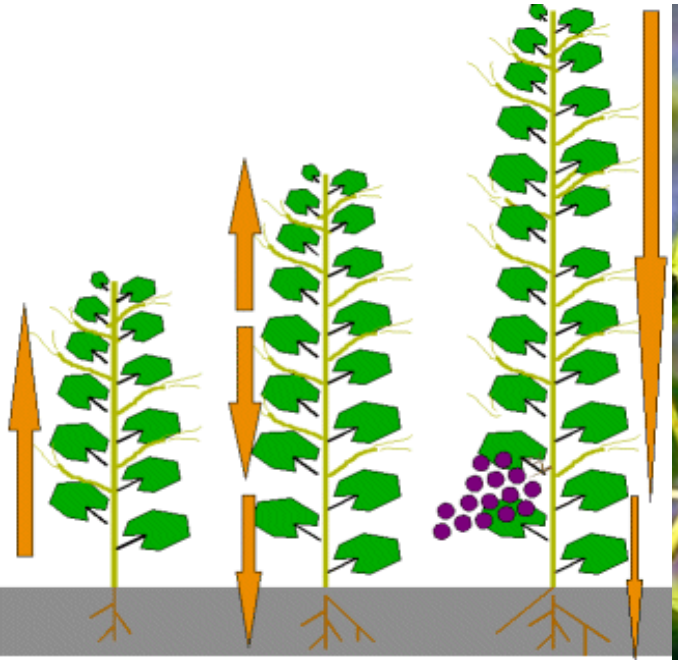


Use but beware of competition!

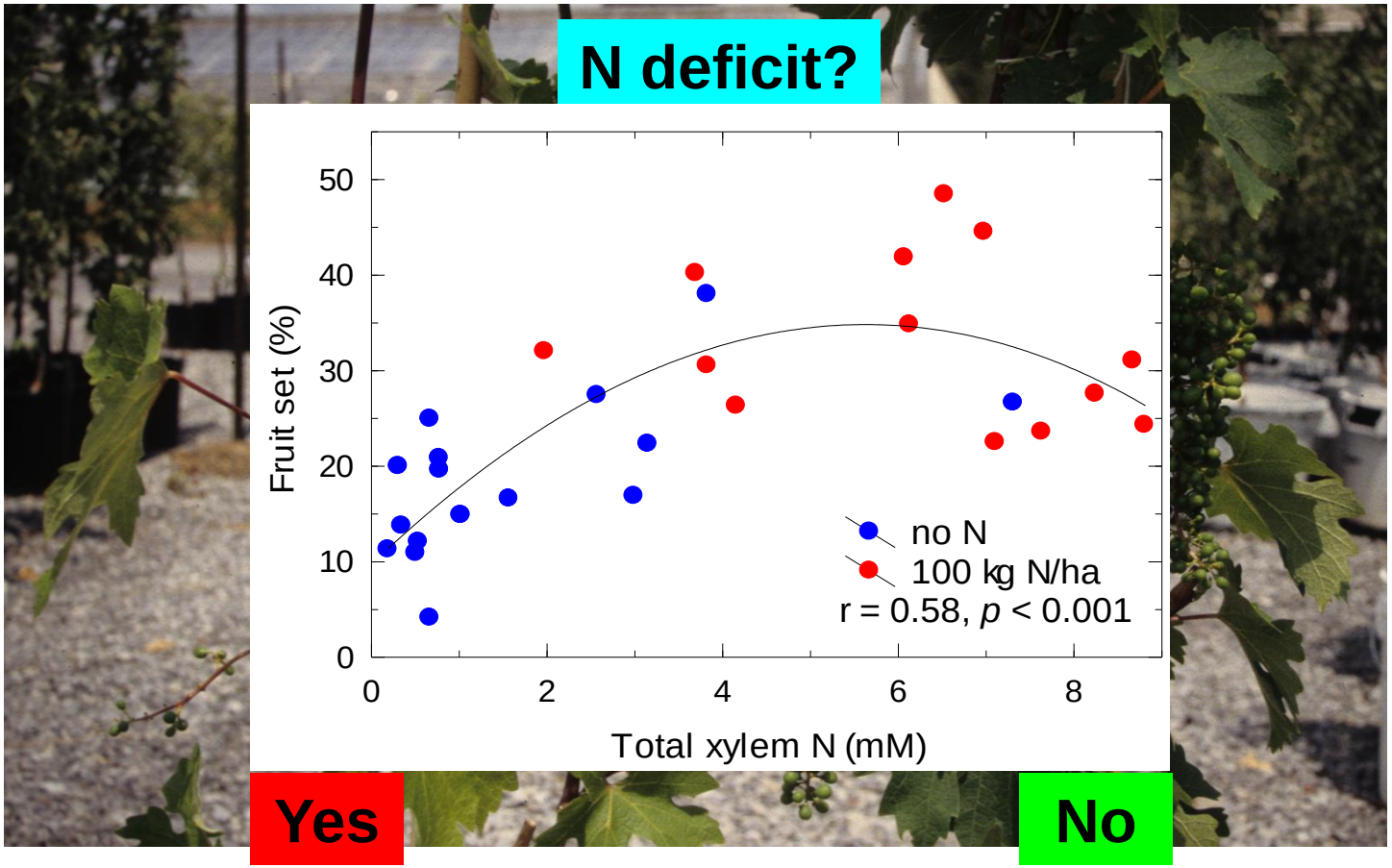
Stress and yield

- 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

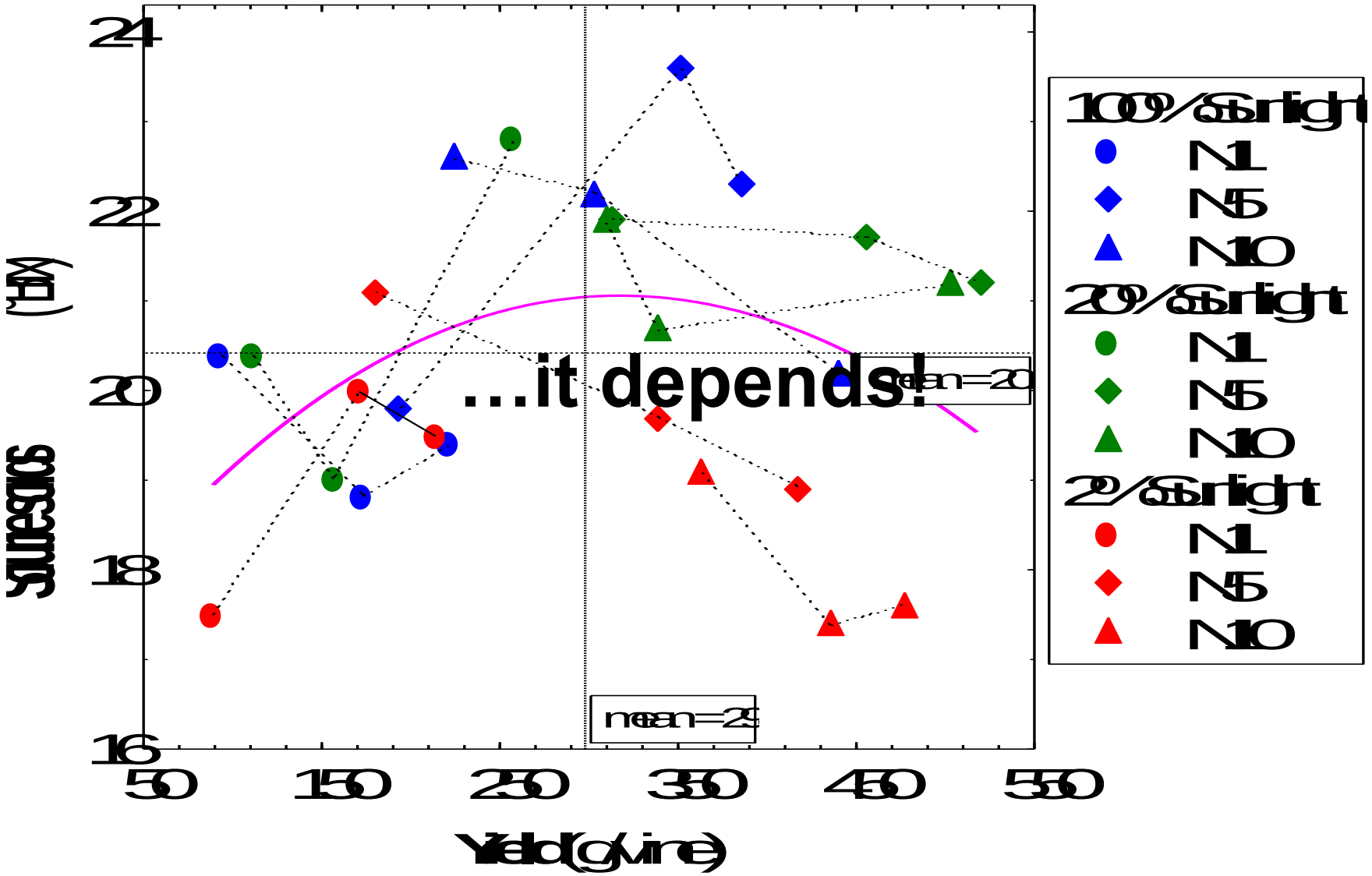


Early stress → Poor fruit set



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

How much N to apply?

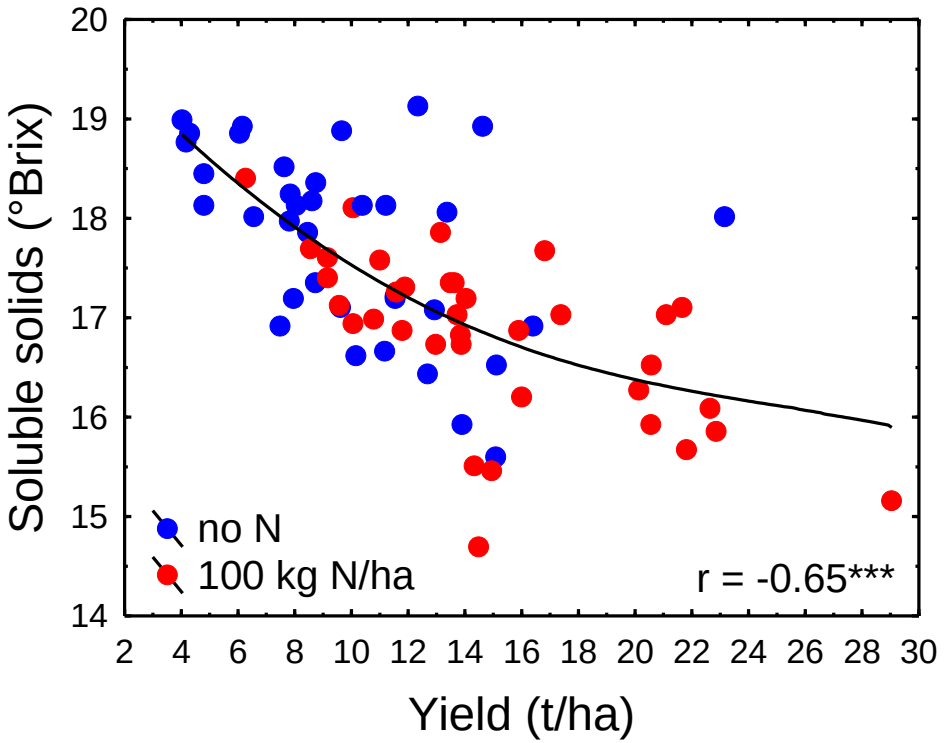


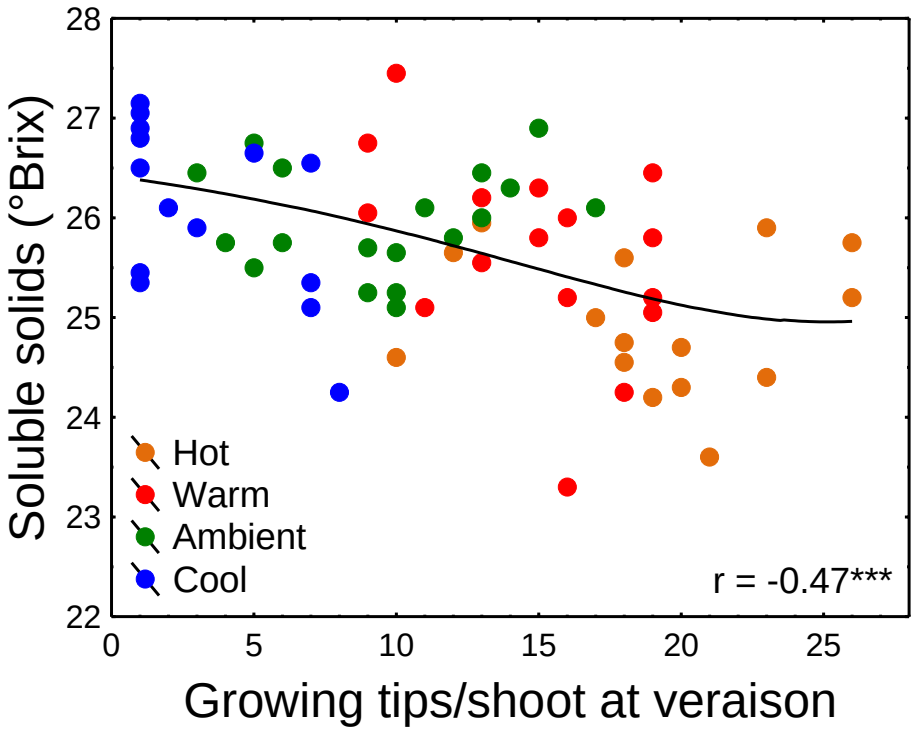
N and fruit quality

- **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

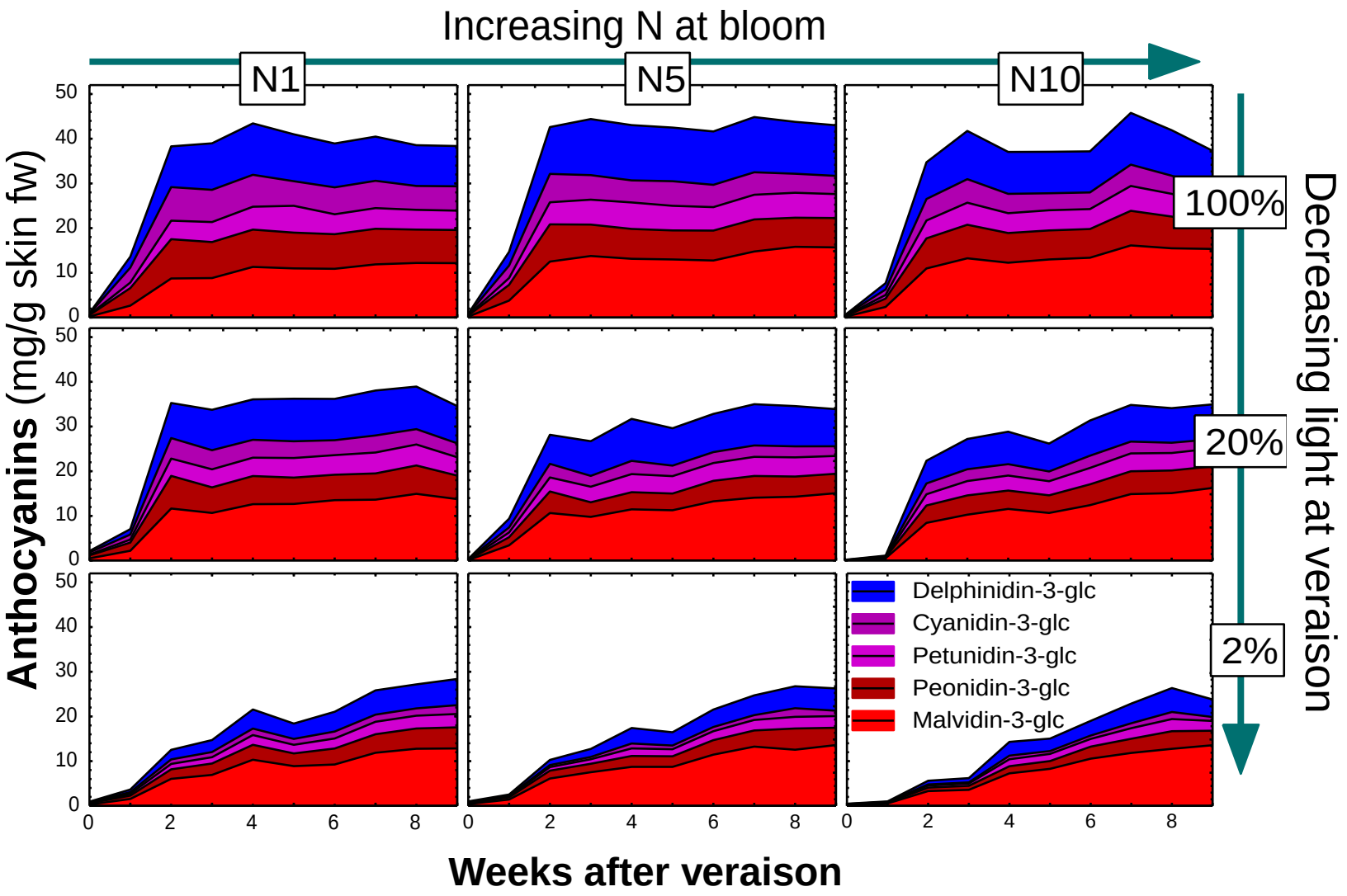
N: Moderation is a virtue





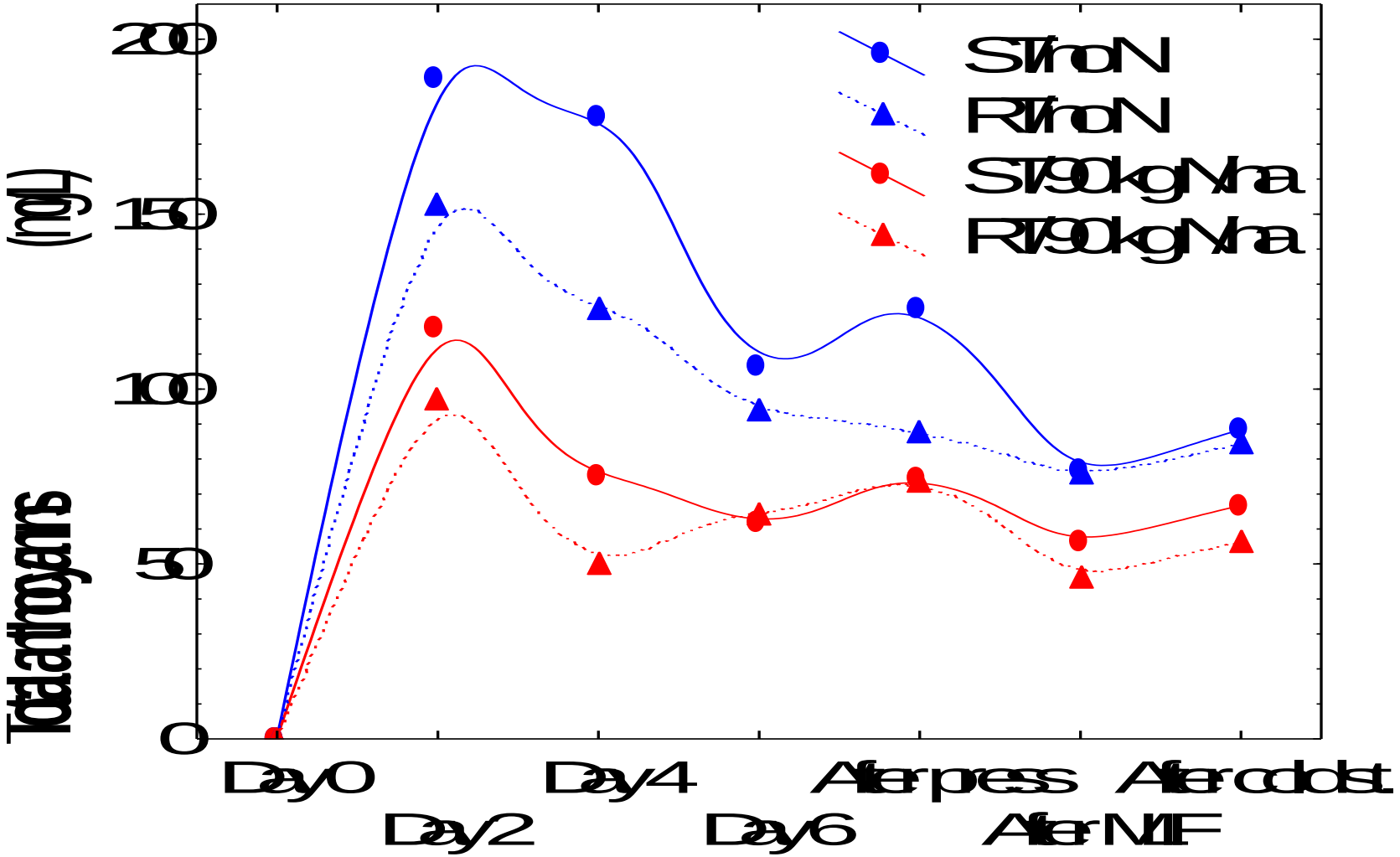
- More N → Higher yield
- More N → More lateral shoot growth, denser canopy
- Growing shoot tips compete with fruit → Delayed ripening
- N suppresses secondary metabolism (phenolics)
- N (and S) enhances volatile thiol precursor production

How to get poor color



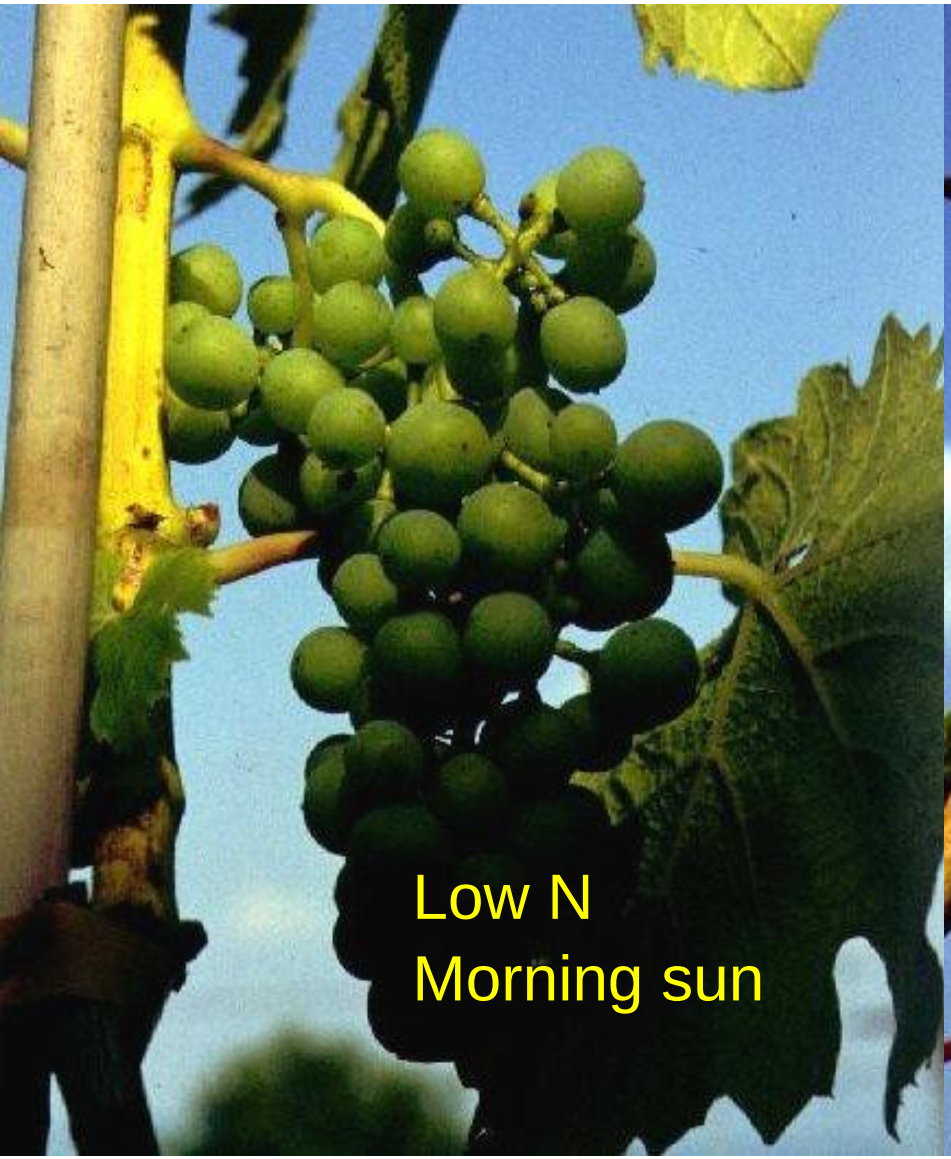
Worst case: High bloom-N + clouds during ripening

Going from bad to worse



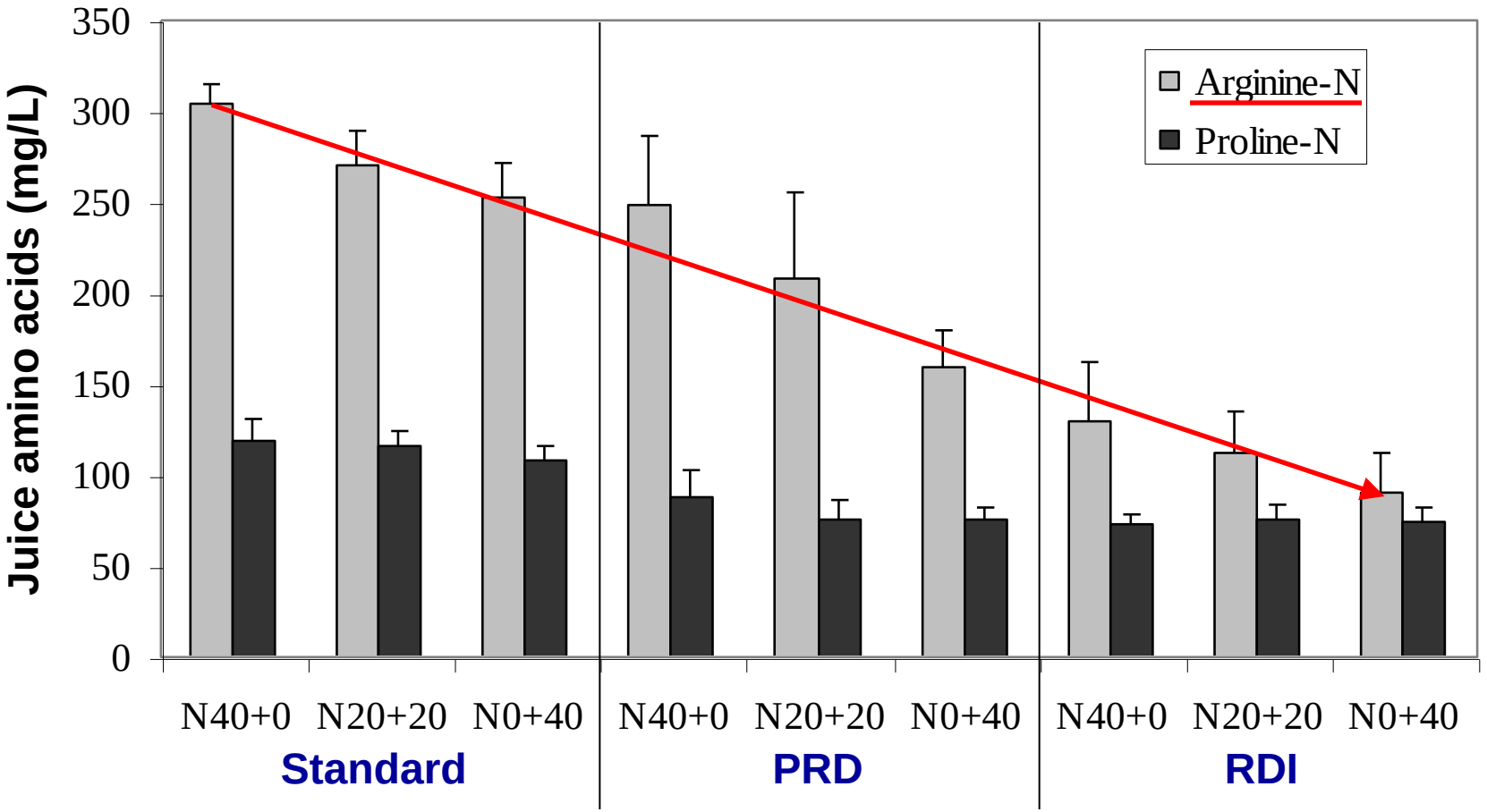
Not possible to solve high-N problems with hedging

Exposure: Too much of a good thing?



N suppresses flavonol production

Nutrition and deficit irrigation



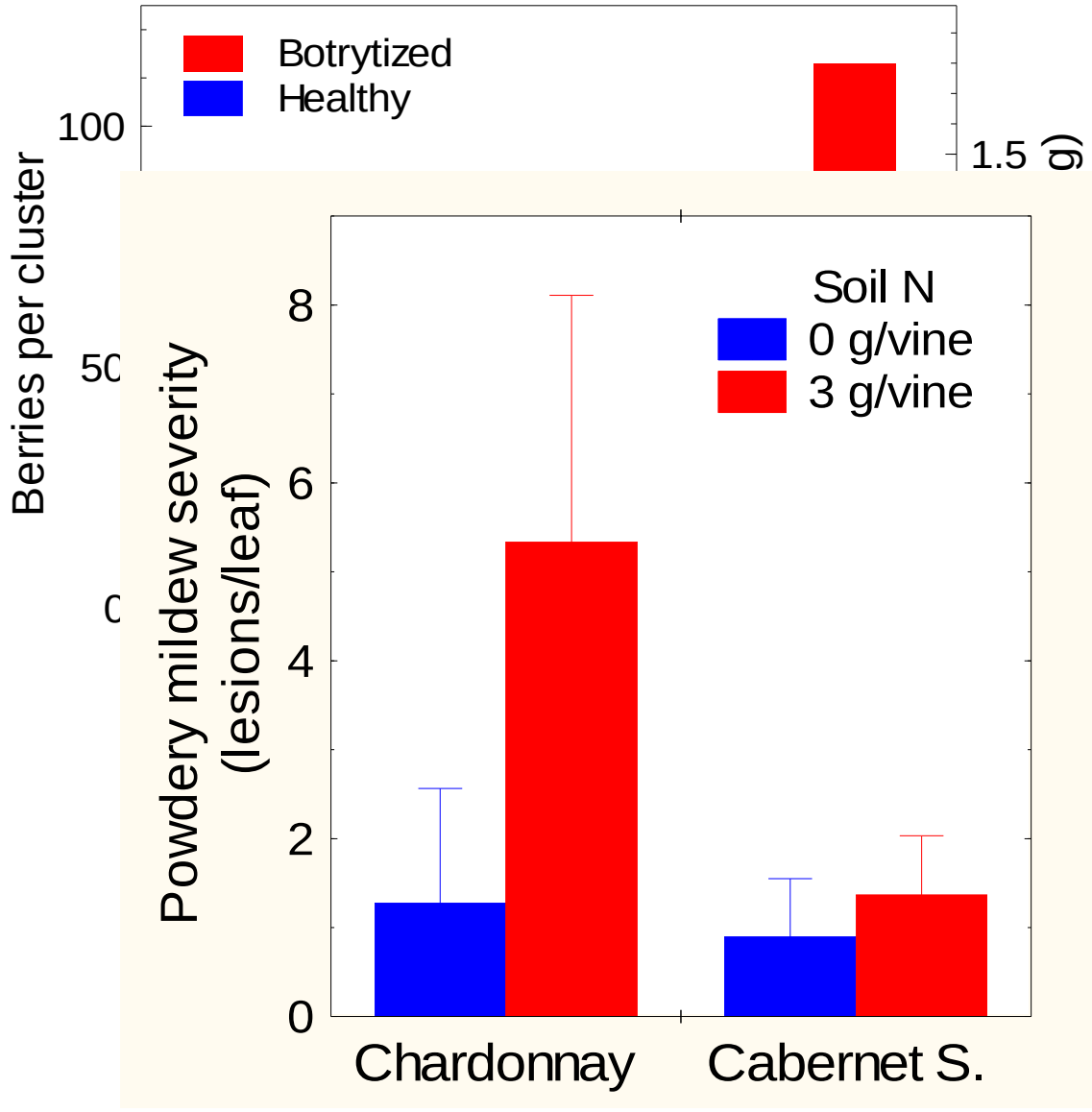
- Food for **yeast**: More N needed with water deficit
- Post-harvest N only with long post-harvest period
- Veraison N as good as bloom N for YAN

The Whites vs. the Reds

- Berry size and sun exposure less important for white grapes (phenolics → astringency, bitterness!)
- Moderate N supply maximizes aroma potential
  → Precursors of volatile thiols (mercaptans)
  → ‘Blackcurrant’, ‘passion fruit’, ‘grapefruit’, (‘skunk’!)
- Low N → Low YAN (<150 mg/L) → Sluggish/stuck fermentation → H_2S (‘rotten eggs’!)
- More N may delay ripening
  → Acid/flavor retention (advantage in hot seasons)



High N → 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

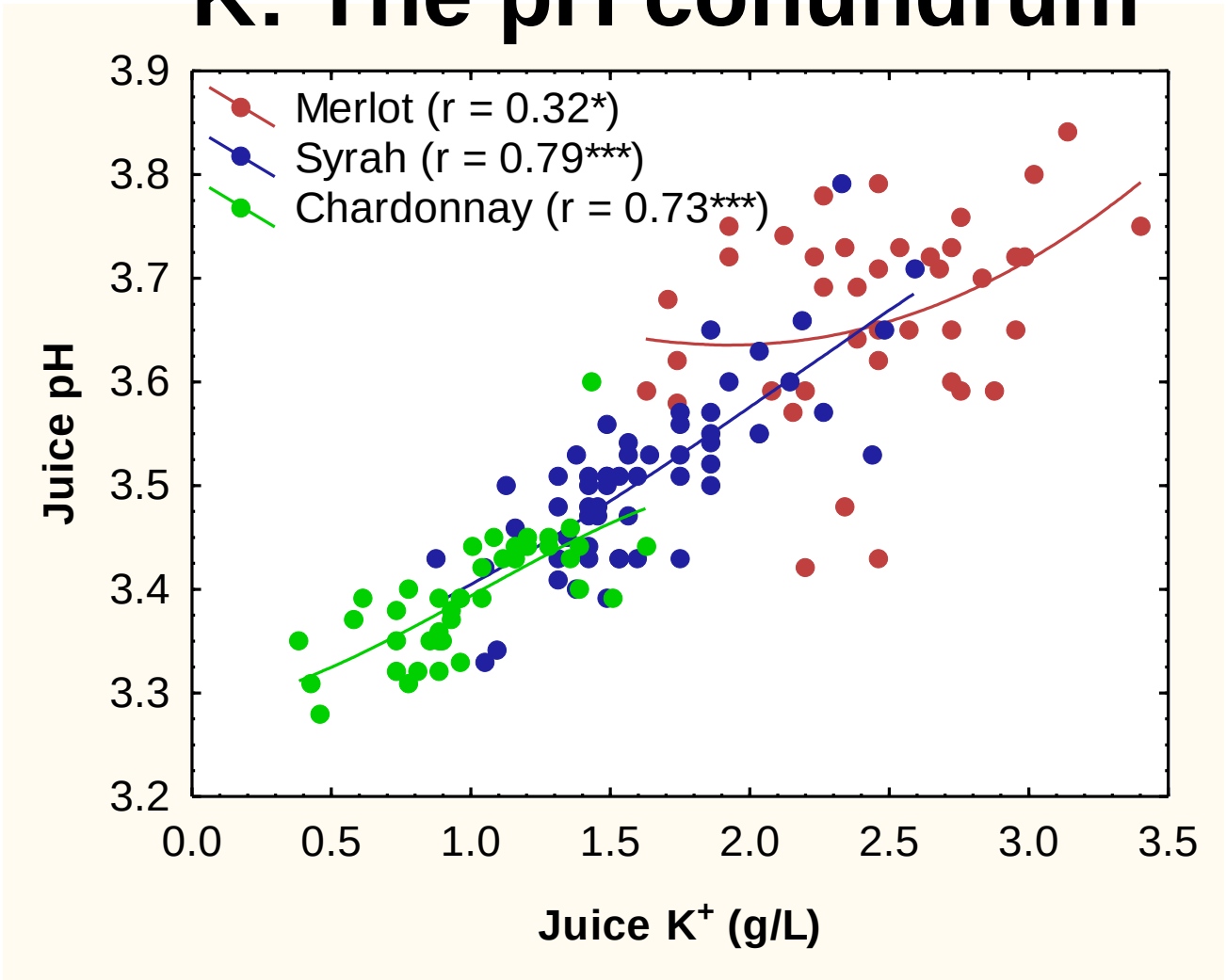
  (stable at low pH, high temperature (>120ºF), ethanol)

  → Oxidizes phenolics

  (hydroxycinnamates, anthocyanins, tannins)
- Oxidation products (quinones) oxidize other compounds (ascorbate, SO_2)
- 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!

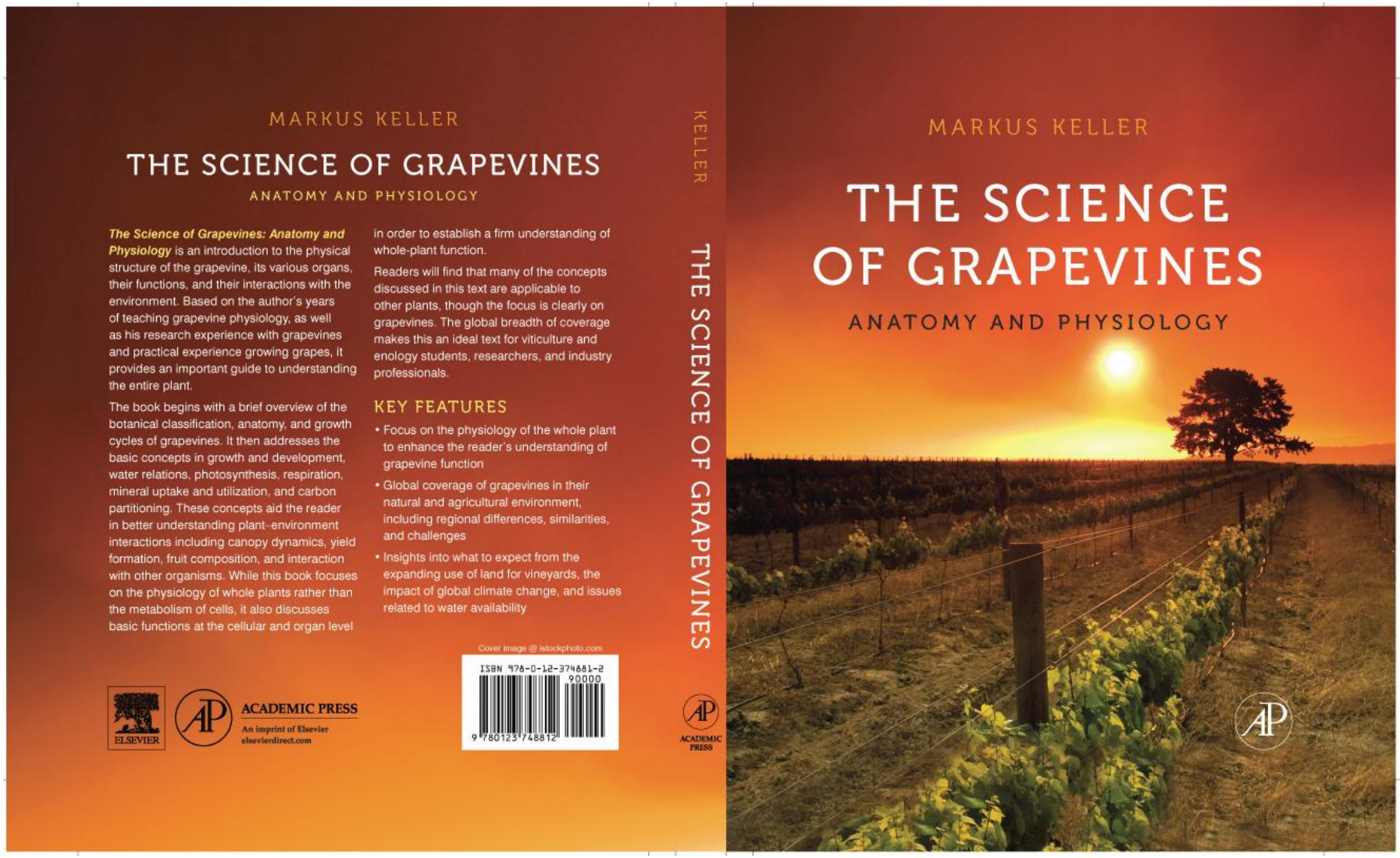
K: The pH conundrum



- 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)

When to apply nutrients?

The good news: It's in the book!



www.amazon.com/Science-Grapevines-Anatomy-Physiology/dp/012374881X