Advanced Grapevine Nutrient Management

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NUTRIENTS ESSENTIAL FOR NORMAL GRAPEVINE GROWTH AND DEVELOPMENT

Obtained from air and water	Macro-nutrients	Micro-nutrients
Carbon (C)	**Nitrogen (N)**	Iron (Fe)
Hydrogen (H)	**Phosphorus (P)**	Manganese (Mn)
Oxygen (O)	**Potassium (K)**	Copper (Cu)
	Calcium (Ca)	Zinc (Zn)
	Magnesium (Mg)	**Boron (B)**
	Sulfur (S)	Molybdenum (Mo)
		Others (?)

Unusual nutrient considerations

Potassium

> relationship to fruit pH

Calcium

> a means to reduce fruit cracking and/or bunch stem necrosis?

Magnesium

> relationship to K+

Sulfur

> what is the fate of applied S?

Trace or micro-nutrients

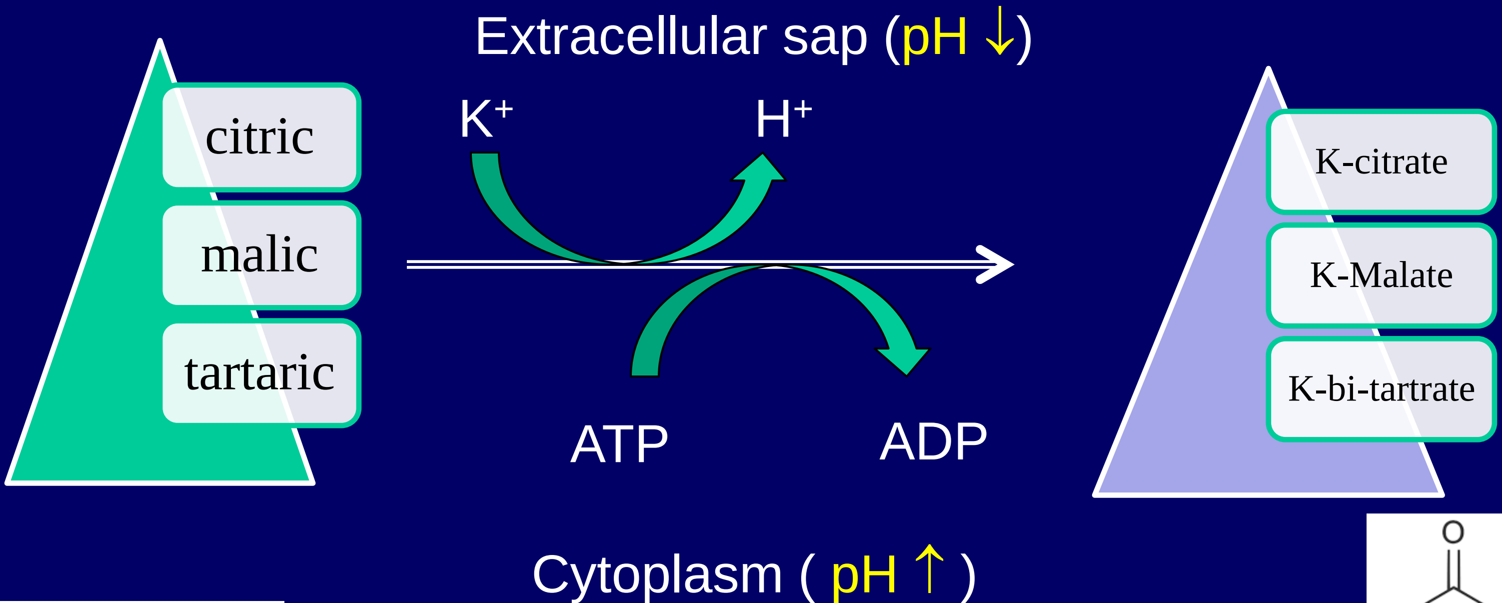
Potassium: role in plants

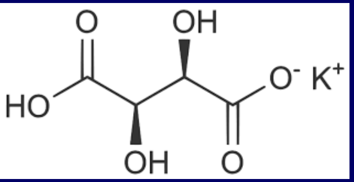
- Phloem loading and translocation of assimilates (sucrose/H^+ cotransport)
- Maintenance of water status
- Enzyme activation (>60)
- Photosynthetic processes

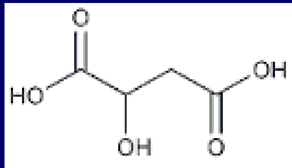
  neutralization of electrical charge

  ATP synthesis

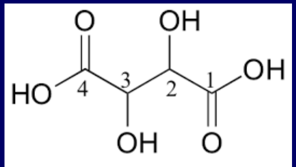
Potassium: role in juice pH?







malic acid

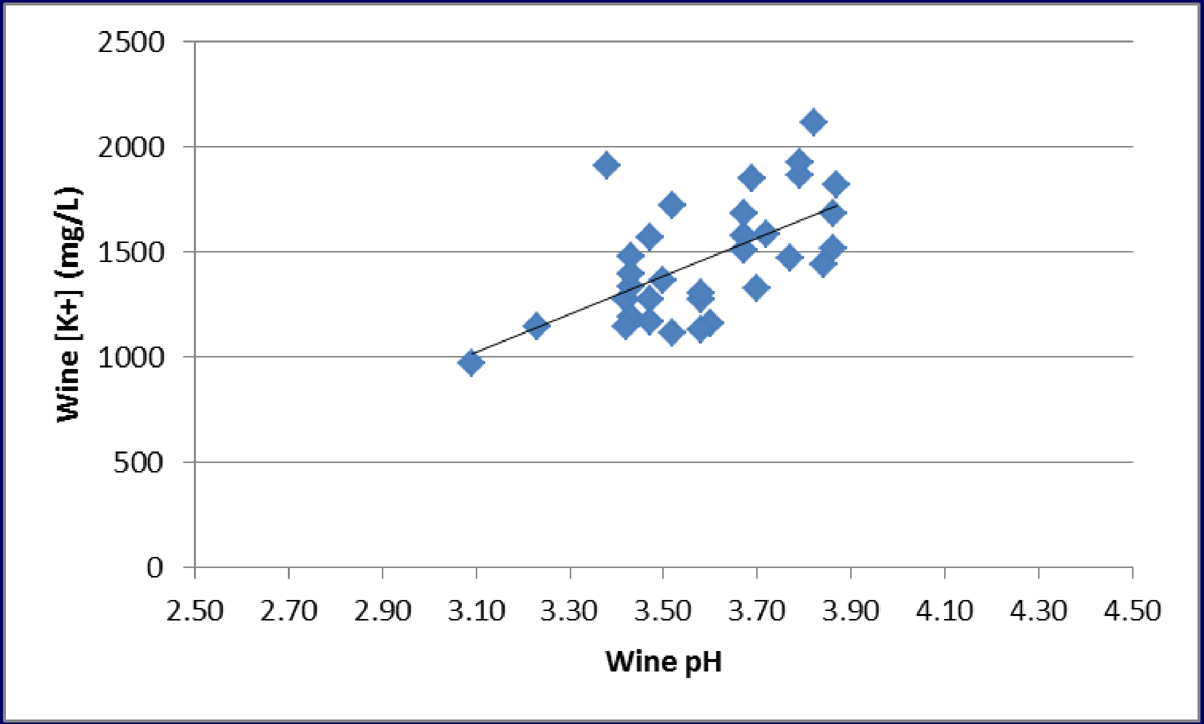


tartaric acid

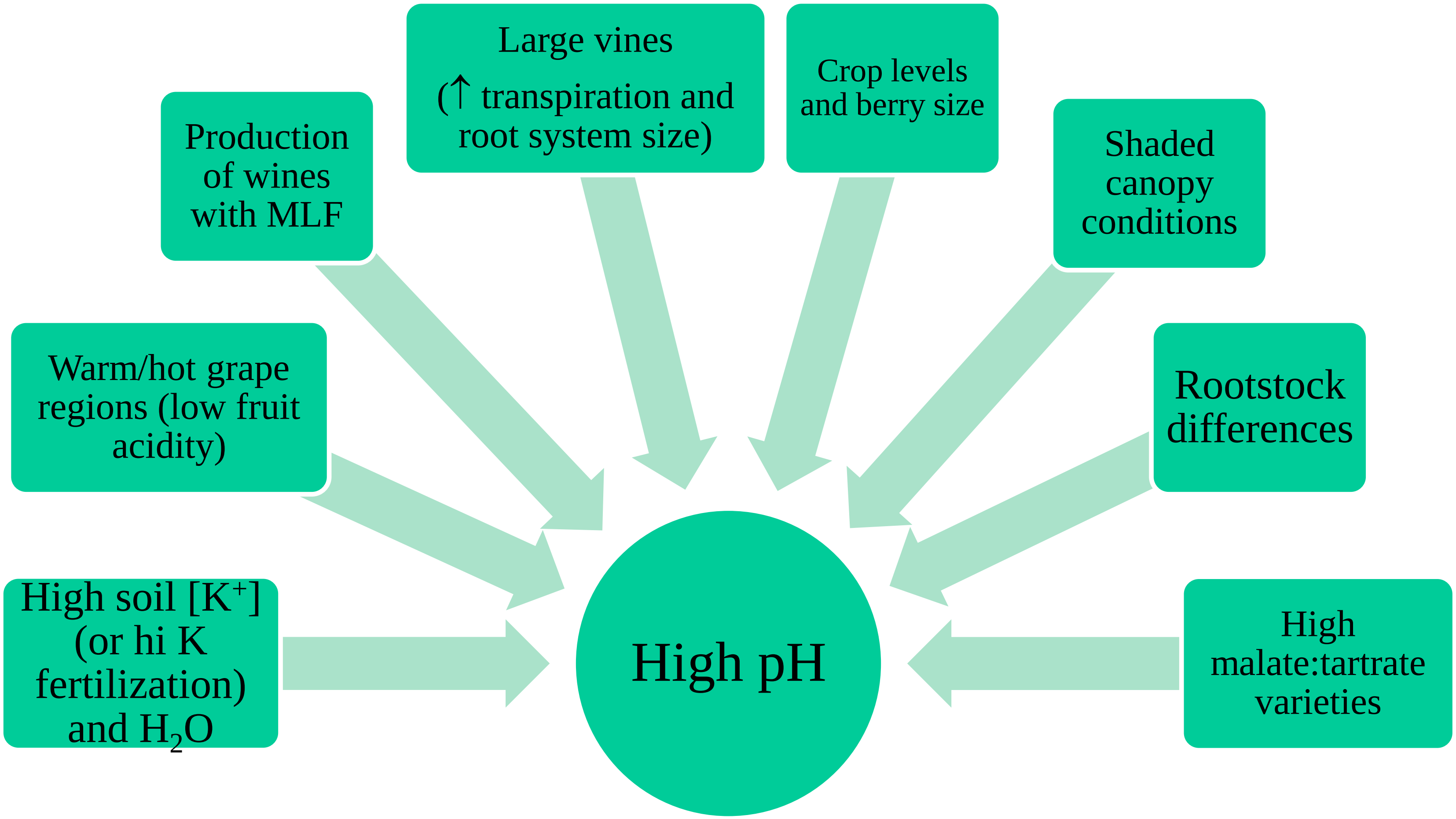
- Tartaric acid is a weak acid: about 1/900 tartaric acid molecules ionize in water (899 molecules remain as tartrate salt).
- Malic acid is even weaker acid. About 1/2500 malic acid molecules ionize in water.

Potassium

Data from Zoecklein “pH imbalance in Cabernet Sauvignon”
ASEV/ES meeting held in Virginia, March 1987
Data from 33 Cab Sauvignon wines from Virginia.



High juice (wine) pH conditions



Potassium

- Relationship between juice [K^+] and juice pH

- Data from Morris et al (1980).
- Utilized Concord grapes, high rates of K+ fertilization; data are means of five years. Fruit homogenized, juice was stored for 6 weeks at 0°C.

K fertiliz. (lbs/acre)	**K (ppm)** Fresh juice	**K (ppm)** Stored juice	**Acidity (% tart)** Fresh juice	**Acidity (% tart)** Stored juice	**pH** Fresh juice	**pH** Stored juice
0	2760a	1030 a	0.97 a	0.71 a	3.31 a	3.37 a
200	3700b	1330 b	0.95 b	0.58 b	3.49 b	3.62 b
400	3880c	1420 c	0.96 ab	0.58 b	3.51 c	3.64 b
800	4190d	1570 d	0.93 c	0.54 c	3.57 d	3.74 c

Potassium

Morris et al. 1987. Am. J. Enol. Vitic., 38:260-263						
Cabernet Sauvignon, 3-yr means						
		Petiole	Juice	Juice	Juice TA	
	t/ac	K (%)	K (ppm)	pH	(% tart)	Brix
No K, no thinning (NT)	5.67	4.50 c	3256 c	3.70 c	0.65 a	19.0 b
No K, cluster-thinned (C-T)	4.95	5.55 b	3577 c	3.76 b	0.61 ab	19.4 ab
6.0 lbs K2SO4/vine, NT	6.02	6.94 a	4379 b	3.83 a	0.62 ab	19.4 ab
6.0 lbs K2SO4/vine, C-T	4.86	7.16 a	4954 a	3.83 a	0.60 b	19.8 a

Potassium (Relationship between juice [K^+] and juice pH)

- Data from Sipiora et al. (2005).
- Utilized Pinot noir grapevines on St. George grown on gravelly clay loam in Carneros AVA
- 0 vs. 8 lbs of K_2SO_4/vine (>5K lbs of K_2SO_4/acre)
- With (supp) or without supplemental irrigation to maintain FC
- Took until 2nd year to see effects of added K+

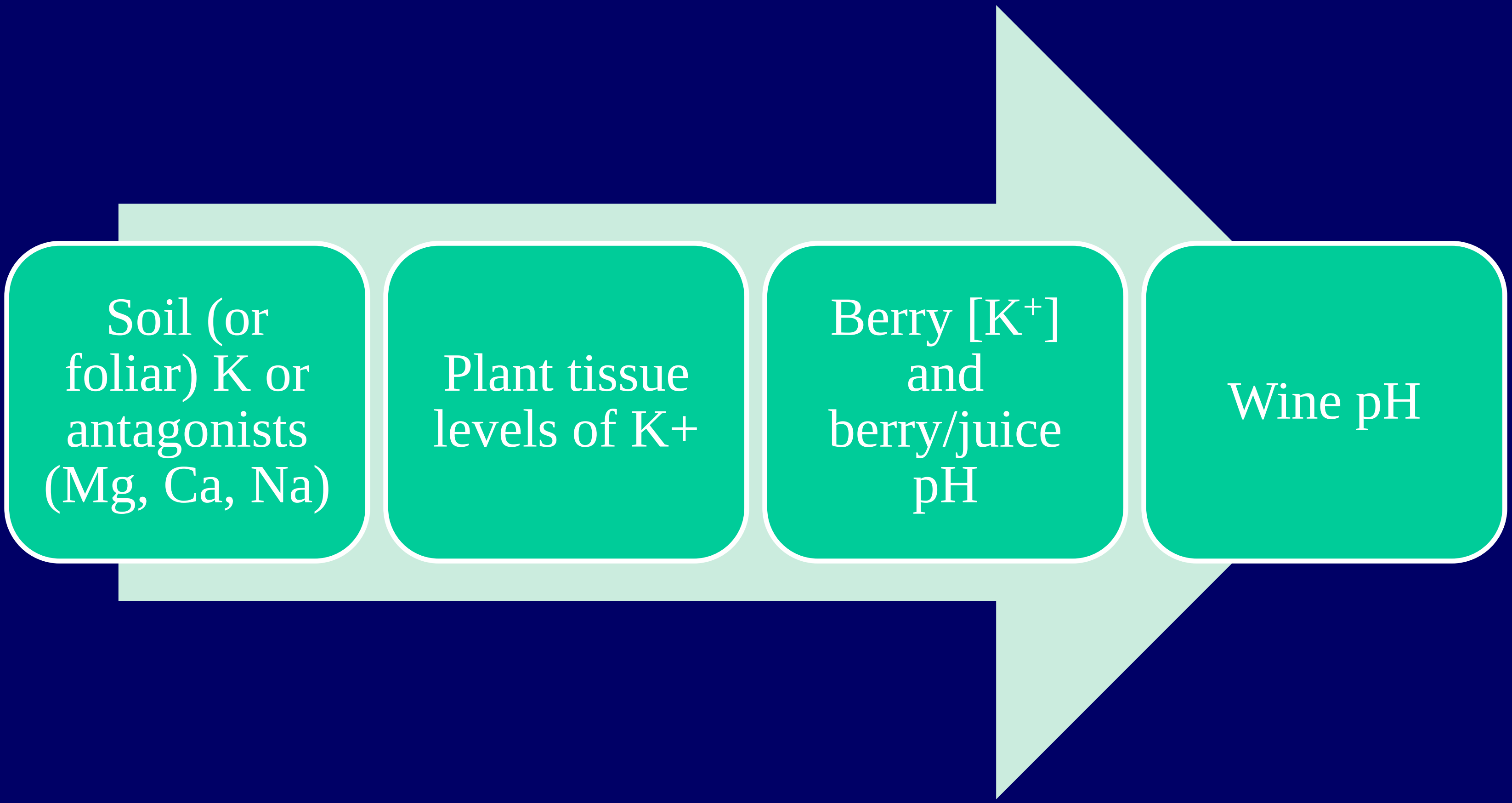
Treatment	Harvest petiole [K] (%)	pH	Juice [K+]	TA (g/L)	Brix
1989					
0-std	0.24	3.29	1550	9.60	21.4
0-Supp	0.51	3.25	1673	11.40	22.5
K-Std	0.58	3.22	1691	10.70	22.1
K-Supp	1.23	3.14	1759	12.40	20.9
Significance					
K fert	***	ns	ns	ns	ns
irrigation	***	ns	ns	**	ns
1990					
0-std	0.35	3.10	1311	8.90	22.3
0-Supp	0.64	3.13	1389	9.90	22.8
K-Std	1.23	3.23	1558	9.00	23.1
K-Supp	1.88	3.19	1540	10.10	22.2
Significance					
K fert	***	***	***	ns	ns
irrigation	**	ns	ns	***	ns

Potassium (Relationship between juice [K^+] and juice pH)

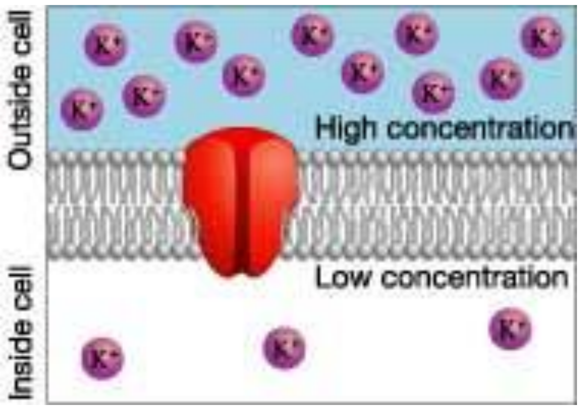
Okay – added potassium fertilizer at fairly high rates can increase berry K^+ and can, under some conditions, elevate juice (and wine) pH.

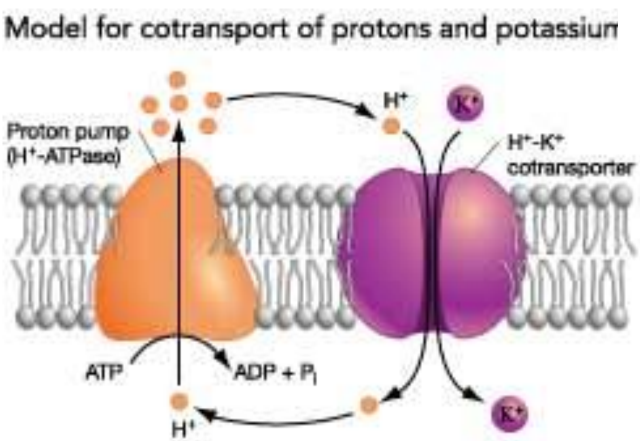
Can juice pH be lowered by depressing K^+ uptake and/or accumulation in berries?

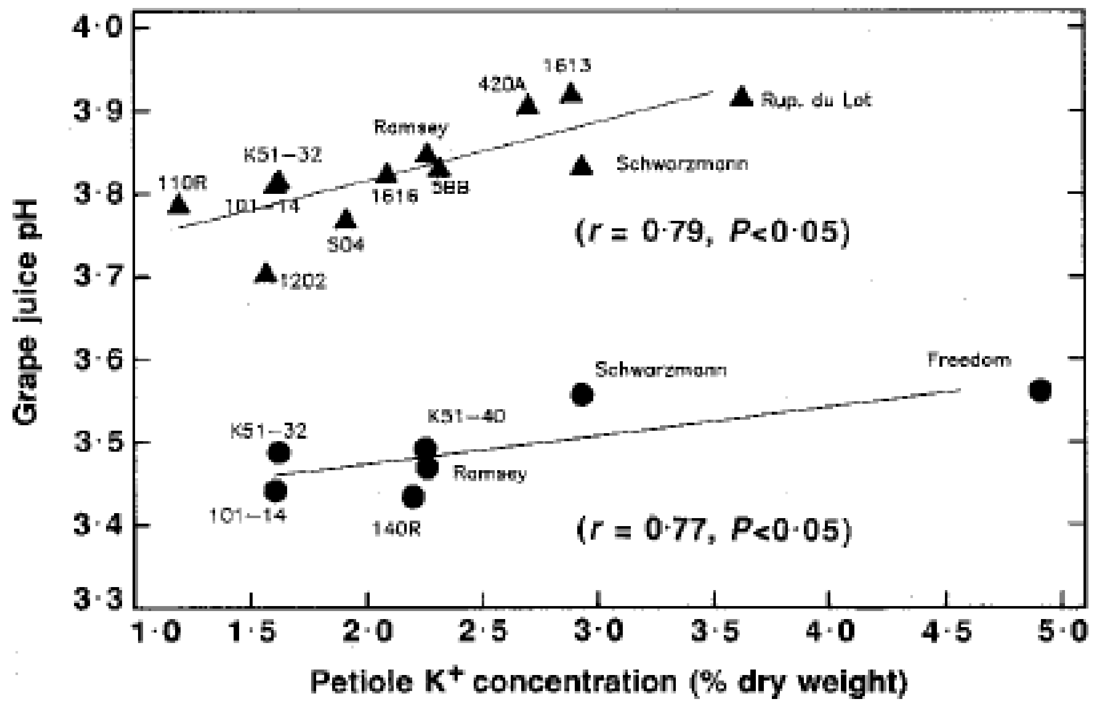
Potassium (Relationship between juice [K^+] and juice pH)



Two uptake models



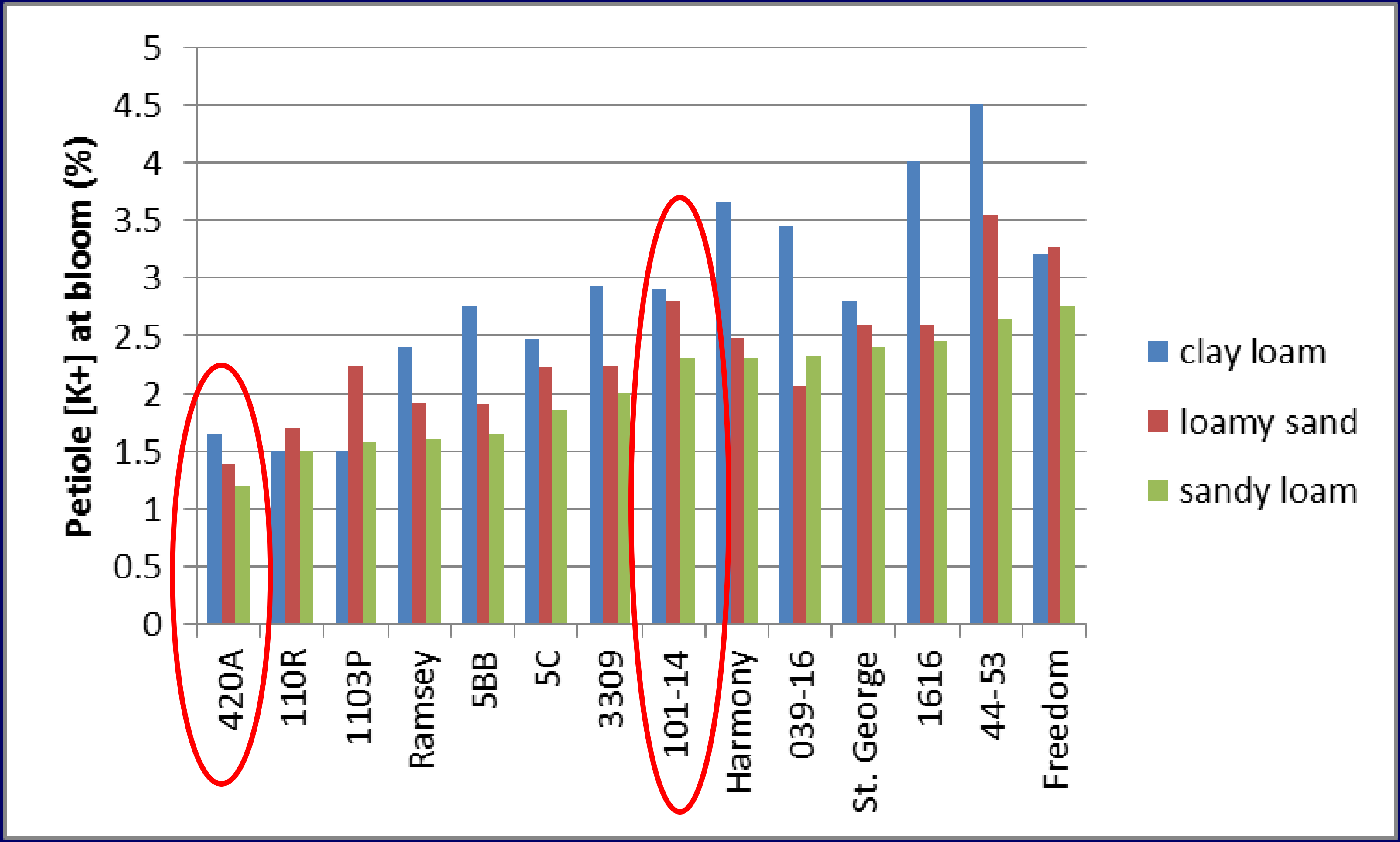




Relationship between [K+] in petioles of rootstocks and the grape juice pH of Chardonnay (▲) and Ruby Cabernet (●).

From Ruhl et al. 1988.

Potassium



From Wolpert et al. 2005. Lower petiole potassium concentration at bloom in rootstocks with *Vitis berlandieri* genetic backgrounds. Am. J. Enol. Vitic. 56:163-169. Data are means of 3 sequential years.

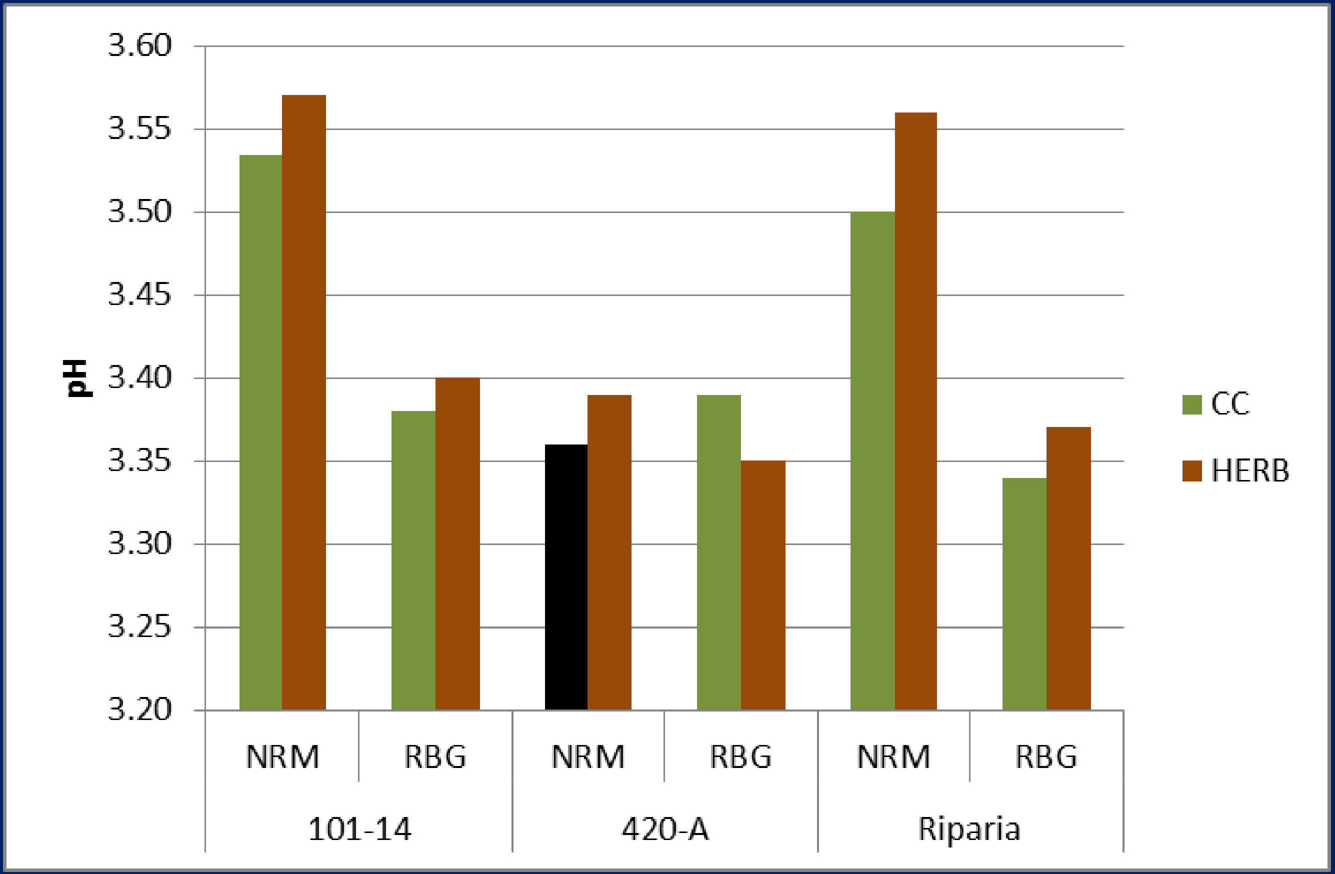
Cabernet Sauvignon tissue [K^+] as function of ground cover, root manipulation and rootstock. Winchester AREC

	2011 season K^+ (%)			2012 K^+
	Bloom petioles	Véraison Petioles	Véraison Blades	Bloom petioles
Herb	**2.01 b**	**3.84**	**0.90**	**2.73**
CC	**2.61 a**	**3.80**	**1.01**	**2.94**
NRM	**2.12**	**5.45 a**	**1.16 a**	**-**
RBG	**2.50**	**2.20 b**	**0.75 b**	**-**
420A	**1.47 b**	**3.05**	**0.82**	**2.13 b**
Riparia	**2.59 a**	**4.00**	**0.98**	**3.16 a**
101-14	**2.86 a**	**4.41**	**1.05**	**3.24 a**

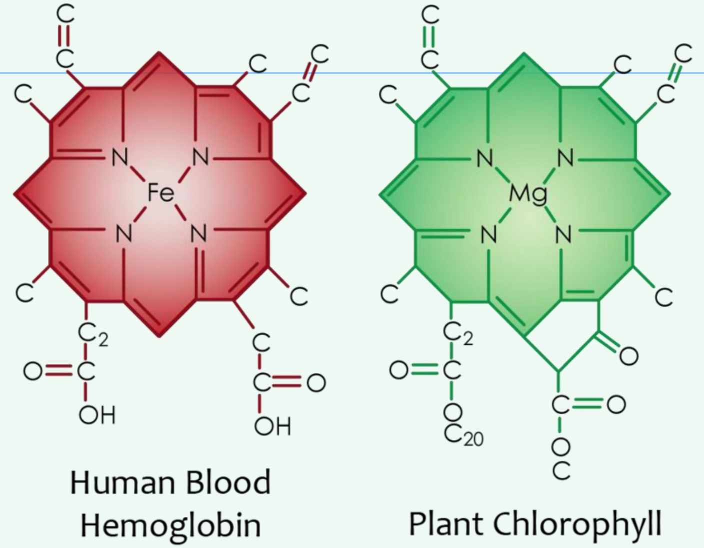
Average <u>juice pH at harvest</u>, 2012-2014, Cabernet Sauvignon, AHS AREC

Treatments:

- 3 rootstocks
- 2 floor management schemes (solid cover crop [CC] or interrow CC+ in-row Herb strip (HERB)
- 2 root manipulations: none [NRM] or rootbags [RBG]



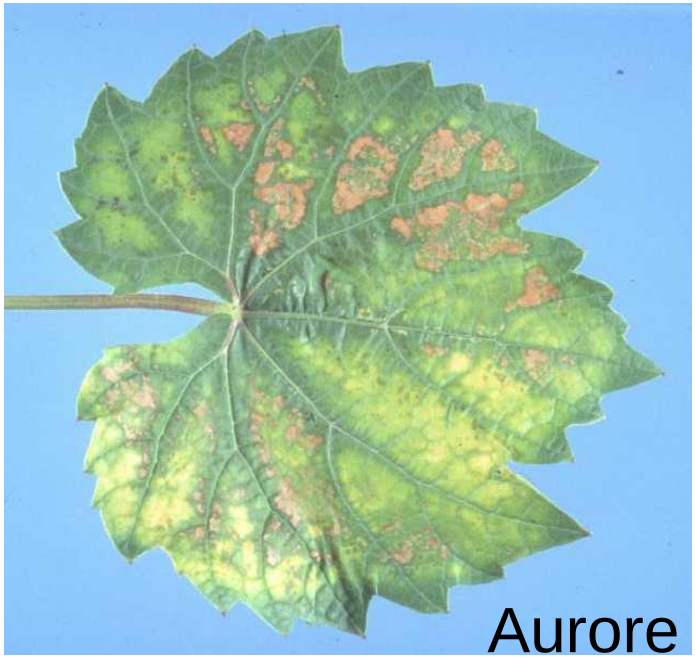
Magnesium



- component of chlorophyll molecule
- Cofactor to activate many enzymes
- Mg deficiency more common in sandy, acidic (< 4.5pH) soils, but also under conditions of high Ca and/or K availability (and Na in saline soils).
- Rarely deficient in Virginia

EXAMPLES OF MAGNESIUM DEFICIENCY SYMPTOMS

Chardonnay: 0.19% Mg in petioles, Piedmont Vineyards, 1986 (Chard is suscept to low Mg)



- Symptoms typically on basal to mid-shoot leaves (a mobile element).

- More common with low soil pH (< 5.5)

- Impact on fruit yield and quality not well quantified.

EXAMPLES OF MAGNESIUM DEFICIENCY SYMPTOMS

- Symptoms on red-fruited varieties may be confused with leafroll virus. How would you distinguish?
- Symptoms more apparent on sun-exposed leaves than more shaded.

- Mg starvation leads to inhibition of phloem loading, breakdown of chlorophyll and increased expression of photoprotective pigments (antioxidant system).
- "Implicated" in expression of bunch stem necrosis in western Europe (low Ca+Mg: K ratio), but we have not seen this in Virginia.

Correction of Mg deficiency

- Pre-plant soil test: 96 to 168 lbs Mg/acre (48 - 84 ppm) desired range (VT Rx)
- Example:
  - Soil test shows 50 lbs/acre Mg and pH of 6.1
  - Rx: adjust pH with dolomitic lime to raise pH to 6.8. This is likely to bring Mg within recommended range
  - If pH acceptable, adjust Mg with $MgSO_4$ (300 lbs/acre [50 lbs MgO/acre]

Correction of Mg deficiency

- Tissue analysis test of mature vineyard:
  - Desired bloom-time values of 0.30 - 0.50%
- Example:
- petiole sample shows 0.19 % Mg; some visual evidence of deficiency
  - Immediate foliar application of Epsom salts at 5 lbs/acre in sufficient water to ensure coverage
  - long-term correction by magnesium sulfate application to soil (banded under trellis).

Calcium

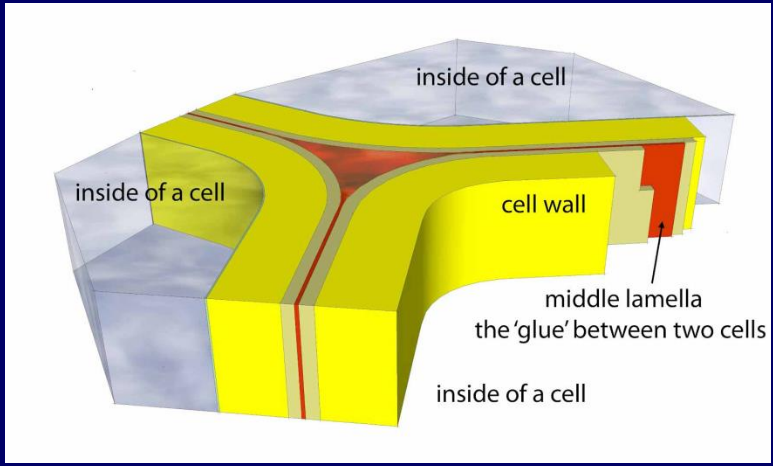
- Structural integrity of cell walls
- Critical to growth, but Ca, like K is not incorporated into organic molecules of the plant.
- Ca-oxalate (defensive?), but also a sequestering to avoid cellular calcium toxicity
- Membrane integrity (cross-links lipids and proteins in the membrane. [bunch stem necrosis, PBA?]
- Electron transport in photosystems

Calcium

- Recommended ranges in plant tissue and soils
  - Plant: bloom-time petioles typically in range of 1.0 to 2.5%
  - Soil: Depends on CEC and soil texture; usually adequate if soil pH is within acceptable range.
- Correction of low levels
  - Liming: ground limestone v. dolomitic lime (Bates presentation)
  - If Ca:Mg ratio > 3.0, use dolomitic lime
  - Gypsum $(CaSO)_4^-$) has been trialed

Calcium

- Structural integrity of cell walls
  - Pectate acts as a chelator to bind calcium and form cross links that hold adjacent pectate polymers (and thus cell walls) together.
  - "Growth" requires a breaking of these cross links, as well as new pectate and new calcium.



Calcium

- Can calcium be used to reduce cracking of grape berry skins?
  - The concentration of extracellular Ca that crosslinks adjacent pectin polymers may be an important determinant for splitting of fruit after water absorption.
  - Some evidence that sweet cherry cracking can be reduced with CaCl
  - The results with grapes in this regard have been less satisfactory

Calcium (continued)

- Natural deficiency rare, but possible at low soil pH (<5.0). Al^{+++} becomes easily solubilized and suppresses Ca^{++} uptake at the root surface.
- Toxicity also rare in Virginia, but…
  - At high soil pH (>7.5) $CaC0_3$ can precipitate P, Fe, Zn, Cu, and Mn rendering these nutrients less available to the plant.
  - Lime-tolerant vs. lime-sensitive (sometime reported as sensitivity to carbonate
  - *V. riparia* = lime sensitive; *V. berlandieri* is lime-tolerant

Calcium (continued)

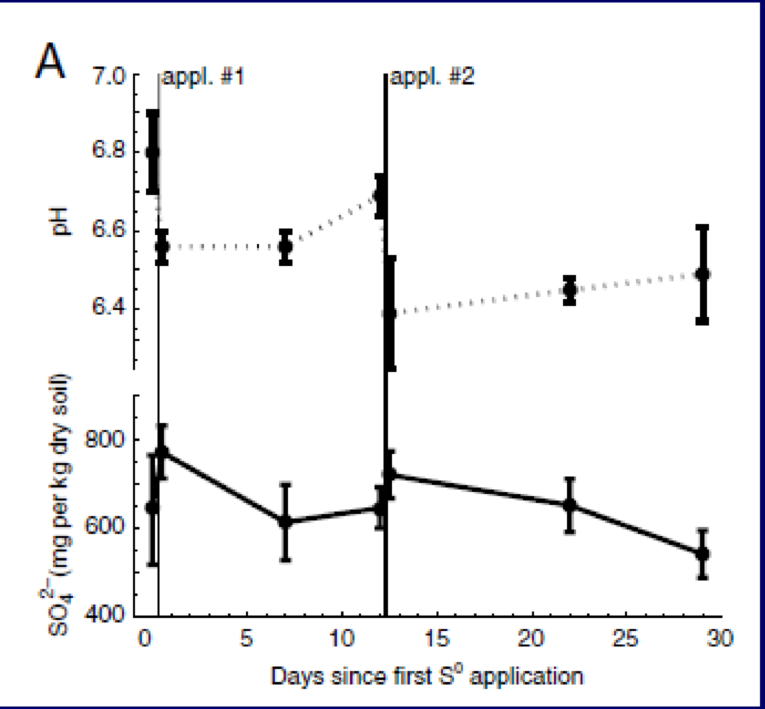
- Norton, lime-sensitive?
  - Case of lime application to soil (starting pH was 6.0). Tissue analysis showed depressed S, P, and K in symptomatic leaves – somewhat lower than in corresponding "healthy" leaves.
  - More acute symptoms on sun-exposed surfaces

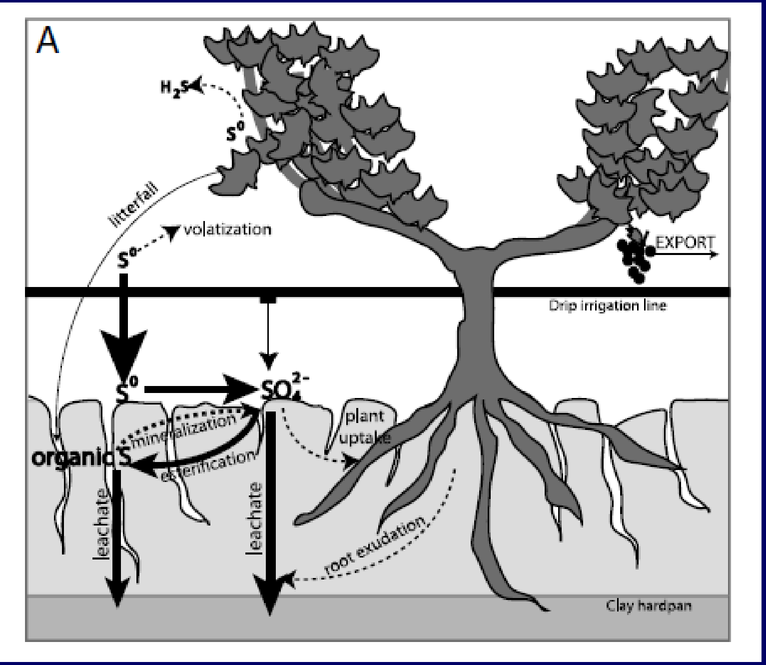
Sulfur

- Structural component of some amino acids, enzymes and structural protein
- Catalyzes the conversion of inorganic N into protein
- Catalyst in chlorophyll production
- Promotes nodule formation in legumes
- A component of certain wine odor-active compounds such as thiols and mercaptans
- No known deficiencies observed in Virginia
- Fate of fungicidal sulfur application to vineyards?

Sulfur

- From: Hinckley and Matson (2011) PNAS 108:14005-14010
- ≥ 90 lbs of S/acre/year (Napa AVA)
- $S^0 \rightarrow SO_4^{2-}$ (rapid oxidation)
- Vegetation = 10-23% of applied S^0





- Rapid soil pH reduction (and recovery in these soils – high buffering capacity)
- Loss of sulfates and organic S via water flushing during dormant season

Micro-nutrients

Very small concentrations needed by the plant for normal growth and development

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

Copper is often applied as fungicide while others (Mn and Zn) are fungicide components.

Iron (Fe)

- Deficiency rare in Virginia, but possible with high pH soils (>7.0) and with American spp. (e.g, Norton)

Photo credit: Peter Magarey

Boron toxicity symptoms in Virginia (left) and Long Island (right)

Desired petiole boron range is 30 to 60 ppm; however, we are unlikely to see B deficiency symptoms above 20 ppm.   Soils that test at < 0.3 ppm typically correspond to petiole B of < 30 ppm.

Boron

	Soil	Bloom petiole	70 – 100 DAB	And	Then
If <	0.3 ppm	20 ppm	20 ppm		Apply Boron as recommended
If =	0.3 – 2.0 ppm	25 – 50 ppm	25 – 50 ppm		No action necessary; repeat sampling in 2 years
If >	2.0 ppm				Monitor for B toxicity
Sources:		Solubor (20% B); can be applied to soil or to foliage Borax (11% B); Borate-46 (14% B); Borate-65 (20% B)			
Rates:		Soil application rates of 1 lb.B/acre in medium to coarse textured soils to 2 lb.B/acre on heavy clay soils are recommended. Foliar application of 0.2 lb B/acre. (1 lb. Solubor) are recommended and no more than 0.5 lb. B/acre (2.5 lb. solubor) in one application. Spring foliar sprays are timed at 6-10 inch shoot growth and 14 days later. In California, fall (immediate post-harvest) foliar sprays have been more effective than spring foliar application in eliminating cluster and berry disorder. To reduce the risk of foliar burn, do not apply boron sprays at less than 14 day intervals or tank-mixed with water-soluble packages, oil, or surfactants.			

Summary

- Promoting and sustaining balanced vine nutrition is part of good vineyard management.
- Starts in pre-plant phase and includes appropriate pH adjustment.
- Three-part process thereafter: soil testing, visual assessment, and plant tissue analysis.
- Corrective measures are generally well-tested and effective, if followed.