Grapes 101

Potassium - From the Soil to the Wine

By Raquel Kallas

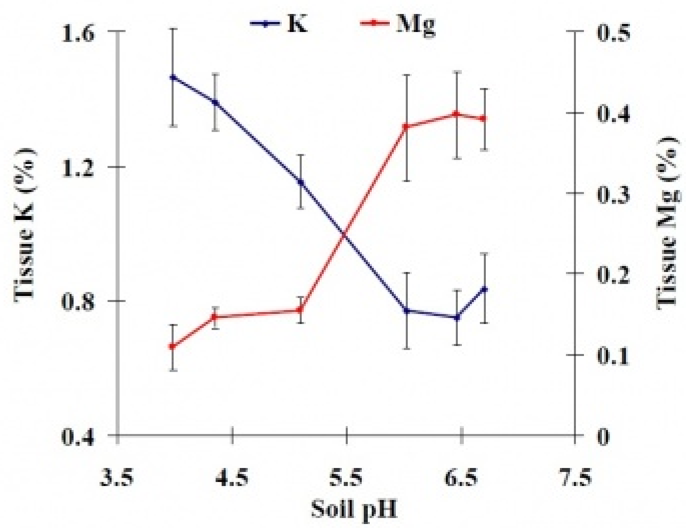
Potassium deficiency symptoms. Photo courtesy of Hans Walter-Peterson

Potassium (K) is the most abundant cation in plant tissues, grapes, juices, and wines. Several factors affect K availability in the soil, K uptake by vines, concentration of K in the fruit, and ultimately the concentration of K in juices and wines. As with anything in viticulture, one size does not fit all in regard to K requirements and recommendations. However, understanding the grand scope of K relations from soils to wines can assist with making the best K management decisions specific to a site and situation.

Function of K in vines. Unlike most other nutrients, K is not metabolized to become part of the structural components of vines. It remains in its molecular ionic form, and plant membranes are highly permeable to it. The following are the roles of K in all plants:

- Enzyme activation
- Cell membrane transport and translocation of assimilates (sugars, etc.)
- Anion neutralization (important for maintaining membrane potential)
- Osmotic potential regulation, critical for water relations and turgor pressure, *the drivers of plant growth and stomatal control*

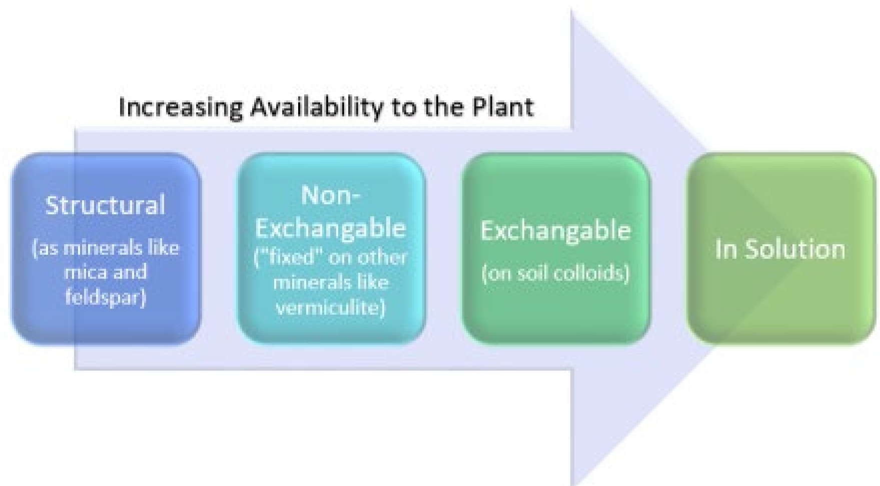
K is primarily phloem mobile, which means that it can be redistributed to different parts of the vine as needed (phloem flows bi-directionally). While a lot of K leaves the vineyard in the fruit every year, it also accumulates throughout the growing season and during post-harvest into storage in permanent woody structures.



Competitive relationship between potassium and magnesium, as influenced by soil pH. Reproduced from Bates 2002

Problems associated with poor K management. K is a major driver of plant growth – in the event of a K deficiency, yield and vigor will be compromised. Every year, K is removed from the vineyard in high quantities in the fruit (Mullins et al. 1992 makes a general estimate of 5 lbs of K removed per ton of fruit per acre), making it an important nutrient to monitor for deficiency and replace regularly. However, there are problems associated with overabundance of K in the vineyard; it is competitive with calcium and magnesium for adsorption to soil particles, so an overabundance of one can lead to deficiencies of the others. In some regions such as Australia, Virginia, and Pennsylvania, excess K is a routine problem and juice and wine quality can be negatively impacted by high concentrations of K in the fruit. In such instances, tartaric acid adjustments are required to remediate juice and wine pH (which can be expensive on a large scale), and may not even resolve the problem entirely because the K concentration is unchanged and can later result in the precipitation of acid as potassium bitartrate. Color, mouthfeel, and perception of quality can also be negatively affected. An example of high K concentration in juice and wine would be 27-71 mmol/L in Australia, compared to 22-32 mmol/L in Bordeaux (Somers 1977). However, high K concentrations can happen anywhere if fertilizer is indiscriminately applied and/or if soil and tissue tests are interpreted wrongly. The best way to address problems associated with K in the juice and wine is to address it first in the vineyard.

K in the soil. Soil pH strongly influences K availability – as soils decrease in pH below 6, K availability and uptake can be inhibited. In New York, soils are generally naturally low in K (less than 200 lbs/acre). Soil texture is another factor: sandy and gravelly soils have relatively low cation exchange capacities, hence low K adsorption. Other factors are organic matter content and soil moisture – low levels of both reduce K availability and uptake. Irrigation can facilitate uptake in drought conditions. Also, calcium and magnesium compete with K for exchange sites on soil particles, and vice-versa. Chances of magnesium deficiency go up when the K:Mg ration is greater than 5:1 (Wolf 2008). Applications of gypsum (calcium sulfate), dolomitic lime, and magnesium sulfate can all reduce K availability to the plant (Wolf 2016).



K in berries, juice, and wine. A number of factors affect K uptake and accumulation in the berries. First and foremost is its availability in the soil. Other factors affecting uptake and accumulation are scion/rootstock combinations, canopy microclimate, and irrigation (Moss 2016). Lastly, K accumulation is differentiated within the berry anatomy.

The literature sometimes conflicts on the effect of rootstocks, but generally speaking, rootstocks with V. *berlandieri* parentage have been shown to take up less K compared to V. *champinii* rootstocks (Wolpert et al. 2005). However, even rootstocks that share a V. *berlandieri* parent may have significantly different K uptake and translocation abilities: 1103 Paulsen has significantly higher K uptake compared to 110 Ruggeri, although both share a V. *berlandieri x* V. *rupestris* parentage (Kodur et al. 2009).

Irrigation is known to increase K availability in solution in the soil, and consequent vine uptake and translocation to the berries. The final result is increased K and pH in the fruit in irrigated vines compared to unirrigated (Freeman and Kliewer 1983). The effects of irrigation and canopy microclimate are coupled, since high water availability increases K transport, as well as contributes to canopy density and shading of leaves (Moss 2016). It has been observed that leaf shading (not fruit shading) due to relatively dense canopies contributes to significantly higher K in Cabernet sauvignon fruit (Morrsion and Noble 1990).

Shoots and leaves require the most K between post-bloom and verasion, during their period of intense active growth. In the berries, K demand and concentration rises sharply after verasion, the period of berry cell expansion. At this point, berries are the strongest sink for K. Within berries, the skin has the highest concentration of K, followed by the seeds, followed by the flesh. This is a factor in some winemakers' decisions when it comes to pressing the grapes – higher press pressure will extract more K, resulting in an increase in must pH. This may be undesirable if you are making base wine for sparkling, for example.

Managing K in the Vineyard. For overall vine performance in NY, the recommended concentrations of soil and petiole K according to Wolf 2008 are:

- Soil: 75-100 ppm
- Petioles at bloom: 1.5% - 2.5% (sample leaves opposite inflorescences)
- Petioles during late summer (70-100 days post-bloom): 1.2% - 2% (sample the youngest, fully mature leaf)

Potassium deficiency symptoms. Photo courtesy of Hans Walter-Peterson

Note that recommendations for Virginia have changed. Regarding sampling methods: soil analyses can show K deficiency in the soil, but petiole analyses are more revealing because they measure what the vine has actually taken up. Taking the petiole samples at bloom provides a chance to adjust if K levels are low before the peak demand from the fruit happens after verasion. However, sampling after verasion is more diagnostic and less variable, and can provide information to base decisions off of for the following season.

Visual signs of K deficiency are scorched leaf edges (progressing to the middle of the leaf over time), low vigor, and low yield. Fertilizer materials have varying rates of K_2O equivalent, or %K. Choose your material based on the amount you need to add, and if you need to supplement additional cations like magnesium. Potassium chloride, a.k.a "muriate of potash" has the highest K_2O equivalent at 60%. Other options include potassium sulfate (50%), potassium nitrate (44%), and potassium magnesium sulfate, a.k.a. "sul-po-mag" (22% K, 11% Mg). Pomace is also an option, but the %K is variable for all of the reasons discussed in this article.

Applying Fertilizers to Correct K Deficiency

	Application rate per vine (lbs.)		Application rate per acre equivalent (lbs., rounded to the nearest hundred)[b]	
Potassium deficiency classification[a]	Potassium chloride (KCl)	Potassium sulfate (K_2SO_4)	Potassium chloride (KCl)	Potassium sulfate (K_2SO_4)
Severe	1.5	2.0	900[c]	1,200
Moderate	1.0	1.3	600	800
Mild	0.5	0.7	300	400

[a] As determined by visual symptom expression or on the basis of plant tissue analysis results.
[b] Based on approximately 600 vines per acre.
[c] Single applications of more than 600 lbs. of KCl per acre are not recommended because of the potential to induce salt burn. Split greater rates into two or more applications over three or more months to allow leaching of chloride ions by rainfall.

Reproduced from Wolf 2008

Conclusion. All of this being said, a framework to estimate fertilizer supply to achieve optimum K concentration in the berry, and consequently in the juice and wine, does not yet exist because the effects of K addition to soil on grapes and wine are so variable. This can be frustrating, since vineyard management of K is the way to influence K in the fruit, juice, and wine, but it's why it's important to understand all of the factors at play so that you can tailor your management practices for any given situation. *Some studies have shown that soil applications of K increase K in the berries, while other studies show no change.* In conclusion, keep in mind that K fertilization impact on vine and berry K is influenced by:

- Amount, type, timing, and frequency of fertilizer
- Soil characteristics
- Root distribution
- Canopy microclimate
- Irrigation
- Rootstock and scion combination

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Raquel Kallas *(M.P.S. '16) is the extension support specialist with the statewide viticulture extension program, based at Cornell AgriTech at NYSAES in Geneva, and a writer and managing editor for Appellation Cornell.*