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Potassium in Soils and Grapevine Nutrition

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Potassium in Nature: Potassium (K) is one of the 16 elements or nutrients essential for plant growth. It is interesting to note that out of the more than 100 elements known to man and listed in the periodic table, only 16 are necessary for plant growth and only 20 play an essential role in life. Potassium is required by plants in large amounts, a macronutrient. The potassium concentration in grapevines can range from 1% to 4% on a dry weight basis, depending on what vine part is sampled and when. That represents a considerable amount of K incorporated into the roots, trunk, shoots, and fruit of a vineyard. Potassium is an abundant element in the earth as well: the earth's crust (rocks and soil) contains about 2½ % K. Potassium is the seventh most prominent element in the earth's crust preceded in abundance by silicon (Si), aluminum (Al), iron (Fe), calcium (Ca), magnesium (Mg), and sodium (Na).

Potassium is an alkali metal and is located in a group (column) of elements on the far left side of the periodic table of elements. Elements in this group have similar chemical properties. Potassium, like sodium and others in the group, is a cation with one positive charge (single unpaired electron); it is a strong reducing agent; it forms metallic bonds with other metals and ionic bonds with nonmetals. Potassium salts (potassium chloride, potassium sulfate, etc.) are soluble because of the low electronegativity of K. As a result, with the weathering of rocks and soil, potassium eventually is released from crystalline minerals and, once in solution, moves to the oceans. Most of the economic sources of K occur in the sedimentary salt beds formed by the evaporation of ancient seas that became separated from the main oceans and from which the contained salts precipitated. Marine evaporites in which K minerals occur are common in many parts of the world and most of the K mined around the world is used for fertilizer.

From Rocks to Soil: Rocks weather into smaller and smaller particles and the minerals in rocks eventually become the primary minerals in soil. The minerals that make up igneous rocks can be grouped into six categories: olivines, pyroxenes, amphiboles, micas, feldspars, and quartz. The potassium feldspars and muscovite micas are rich in K, whereas the olivines, pyroxenes, and amphiboles are relatively poor in K but contain a great deal of iron and magnesium. Potassium feldspar, muscovite mica, and quartz are the major mineral constituents of acid igneous rocks (granite, rhyolite). Granite is the parent material for most of soils on the east side of the southern San Joaquin Valley and, subsequently, these soils have a great deal of potassium both in the primary minerals and secondary clay minerals (weathered primary minerals). In contrast, olivines, pyroxenes, and amphiboles are the major mineral constituents of basic igneous rocks (basalt, gabbro), and soils derived from these rocks are generally low in potassium and high in magnesium.

Quartz (silicon dioxide) is very resistant to weathering and is the primary mineral that makes up the sand fraction of soils around the world. Soils derived from Sierra granite, rich in quartz, are generally coarse textured ranging from loamy sands to fine sandy loams. In contrast, soils derived from basic igneous rocks with no quartz minerals usually are very fine textured. Note: You can see a sand particle with a hand lens or with your naked eye; a light microscope is necessary to see a silt particle; an electron microscope is necessary to see an individual clay particle.

Soil Age and Texture: The K status of a soil can be affected by the weathering and breakdown of soil minerals and leaching of K. On the east side of the San Joaquin Valley, the oldest soils are the terrace soils, red hardpan soils. These soils are a hundred thousand years old, and can be recognized not only by the hardpan that developed in the B horizon but the reddish color of the soil resulting from iron released from minerals in the weathering process. Terrace soils have less plant available K than most young alluvial soils. Fortunately, the low rainfall in the southern San Joaquin Valley has helped preserve soil K in the surface soil. In contrast, the high rainfall of the coastal areas in California, Oregon, and Washington have resulted in soils that are severely weathered and deficient in K.

Sandy soils that have very low content of clay often have less plant available K. Potassium ions are strongly adsorbed on clay. Without the adsorbing ability of clay minerals, the soluble K in sandy soils is easily leached from surface soil. Making matters worse, sandy soils are difficult to irrigate efficiently (unless a drip system is used), and the water applied in excess of the vine's water requirement moves below the root system taking with it soluble K.

Potassium in Soil: The potassium content of soils varies depending on the parent rock and degree of weathering and ranges from ½% to 2½%. That's a lot of K-10,000 to 150,000 pounds in the surface foot. However, most of the K, 98%, is part of the crystalline structure of feldspar and mica minerals and 1 to 10% is trapped in expanding lattice clays. Potassium available for plant uptake is found in the soil solution and on the cation exchange of clay minerals and organic matter and represents a very small fraction of the total K in soils.

Laboratories can evaluate the soil's available K (solution K + exchangeable K). This is done by extracting K from soil using one normal ammonium acetate solution at pH 7.0, and the results are expressed as ppm K in the soil. Values often fall between 100 and 400 ppm. Cotton yields in the San Joaquin Valley have increased with K fertilization when available K in the surface 6 to 18 inches is less than 120 ppm; however, soil K has not been a good criteria for evaluating the K status of grapevines and other perennial crops.

The secondary clay minerals in San Joaquin Valley soil have the ability to both fix and release K in dynamic equilibrium with soil solution and exchange sites. The major clay minerals responsible for K fixation are illite, weathered mica, smectite, and vermiculite. If over the years the interlayers of these clay minerals become depleted, they can fix large amounts of K when fertilzer is applied. Many soils in the San Joaquin Valley have a large fixing capacity and can tie up 50% or more of added K fertilizer, but this K is not lost but rather stored in the interlayers of the clay and slowly released in dynamic equilibrium with soil solution and exchangeable K.

Calcium/Potassium/Magnesium Interactions: Calcium, potassium, and magnesium interact or compete on the soil's cation exchange, and they compete for entry into plants. It has been noted in vineyards in the San Joaquin Valley, particularly with drip irrigated vineyards, that applying calcium over the years, to improve water infiltration, has reduced potassium and magnesium levels in the vine. Also, the application of potassium through the drip system has been implicated in the subsequent appearance of magnesium deficiency. The interaction of calcium, potassium, and magnesium on grapevine nutrition is fascinating and needs to be investigated more thoroughly.

K Fertilization of Grapevines: Potassium deficiency is usually confined to small areas in a vineyard-seldom larger than 1 to 3 acres. Deficiency is likely to occur in cut areas, where the K rich surface soil was removed during land leveling, or on very sandy soils that have low native K fertility. Shallow soil areas, poorly drained soils, and root problems caused by soil pests are also more subject to K deficiency.

Vines severely deficient in K tend to have fewer and smaller tight clusters with unevenly colored small berries. With Thompson Seedless the lower portion of the bunch may collapse by midsummer, resulting in raisined, immature berries by harvest. Much of the effect of K deficiency on the fruit is the result of reduced vine growth and premature leaf fall.

With furrow/flood irrigation methods, massive fertilizer rates are necessary to overcome the high fixation of K in most California soils. Typical application rates for mild to severe deficiencies range from 1 to 3 lbs of K per vine with potassium sulfate the most commonly used fertilizer.

Deep placement of K fertilizer in a concentrated band close to the vine is the recommended application approach. Treatment can correct deficiency for 5 to 10 years, depending on deficiency severity and rate of application. Potassium should be applied late fall to early spring.

Fertilizer efficiency is improved when applied under drip irrigation. With drip, a high concentration of K saturates soil reaction sites in an area of high root density. A fertilizer experiment in drip irrigated vineyard on sandy loam soils in the southern San Joaquin Valley showed correction of severe potassium deficiency with rates as low as 2 pounds potassium sulfate (45% K) per vine. (It would take 4 to 6 pounds of potassium sulfate per vine to correct a similar deficiency under furrow irritation.) In this experiment, rates as low as ½ to 1 pound of potassium sulfate per vine increased K levels in tissue and greatly improved visual symptoms of K deficiency compared to unfertilized vines.

A single application of K with drip is just as effective as multiple applications providing the same amount of K is ultimately applied. However, it is often more practical to apply a little K through the drip system on a weekly basis rather than a large amount all at once. For potassium maintenance, 10 to 15 pounds of K per acre can be applied on a weekly basis for 5 to 10 weeks. Fertilization should be completed before veraison (berry softening).

To correct a severe K deficiency in a small area of the vineyard, potassium sulfate at a rate of 2 pounds per vine is placed by hand in a small excavation made in the soil directly under the emitter. This can be followed up with K applied in small amount through the drip system for overall maintenance.

Potassium fertilizer products used in vineyards include potassium sulfate (K_2SO_4) (dry 45% K, liquid 0-0-6); potassium chloride (KCL) (dry 52% K, liquid 0-0-10); potassium nitrate ($KN0_3$) (38% K + 13% N); liquid potassium carbonate (K_2CO_3) (0-0-30); and liquid potassium thiosulfate ($K_2S_20_3$) (0-0-25+17 sulfur). Potassium sulfate is the most commonly used K fertilizer. Potassium chloride should only be used on well-drained soils with no existing salinity problems and at low rates to avoid chloride toxicity. When using potassium nitrate, the nitrogen content must be considered when determining rates. Potassium carbonate has good solubility and is used on acid soils because of its alkaline reaction. Potassium thiosulfate contains two pounds of sulfur per gallon and is used on alkaline soils because of its acid soil reaction. Liquid formulations of potassium are available with varying concentrations of nitrogen.

Potassium May Slow Water Infiltration: Fertilizing vineyards with potassium (K) using a drip system has become a common practice in recent years. Growers will often apply 10 to 15 pounds of K per acre per week beginning soon after budbreak and continuing for five to ten weeks. It has been an effective technique for increasing the K status of grapevines. However, research at the U.C. Lindcove Research and Extension Center has shown that K applied through the drip system may decrease infiltration rates on some soil types.

There are chemical similarities between potassium and sodium (Na); both are alkali metals with a single valence electron and both are very good reducing agents. It is well known that Na can have a negative effect on soil structure and reduce water infiltration rates. Given the similarities between K and Na, it is reasonable to question whether K added to irrigation water could also reduce infiltration. The objective of the following research was to determine the effect of K (added to irrigation water) on the rate water infiltrates soil under drip irrigation.

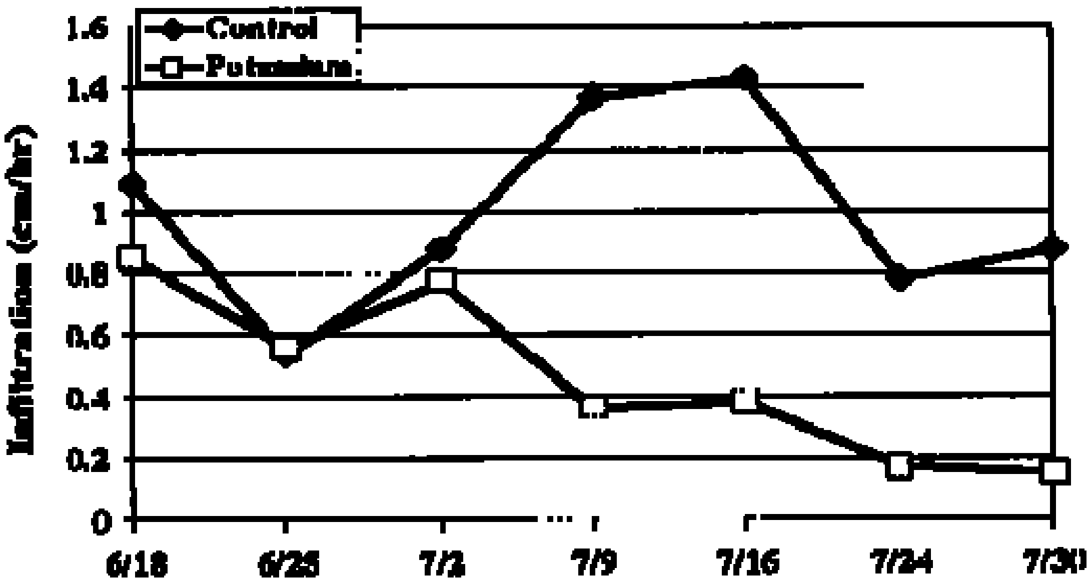
An experiment was conducted at the Lindcove Research and Extension Center near Exeter during the 1996 season. The soil was a San Joaquin sandy loam ("red soil"). The irrigation water was canal water low in soluble salts (60 ppm).

San Joaquin sandy loam is a soil type that can have slow water infiltration rates when low salinity water is used for irrigation. To overcome this effect, growers apply gypsum ($CaSO_42H_2O$) either by spreading it on the soil surface or by mixing it with the irrigation water. With a drip system, gypsum is commonly applied directly to the irrigation water using a gypsum applicator at a rate of about 700 pounds of gypsum per acre foot of water (3 meq/L, Ca).

We applied K to the irrigation water at 3 meq/L, which is equivalent to applying 700 pounds of potassium sulfate (K_2SO_4) per acre-foot of water; we compared this to an untreated control. Drip irrigations occurred three days a week. K significantly reduced infiltration rates (see figure) compared to the untreated control, and the drop in the infiltration rate occurred within two weeks of the first application of K. After four weeks the infiltration rate dropped to less than 0.2 cm/hr (less than 0.08 in/hr) which was one-fifth the infiltration of the untreated control.

In this experiment, K applied to irrigation water had a negative effect on water infiltration; however, this doesn't occur on all soil types. The literature shows a broad spectrum of possibilities for potassium's effect on infiltration, ranging from being similar to sodium to being similar to calcium. This study shows that on San Joaquin sandy loam the effect of K on infiltration (when added to irrigation water at 3 meq/L, K) is similar to sodium.

Effect of Potassium on Water Infiltration



Note: Potassium was applied at 3 meq./L