# Potassium fixation in soils of the Lodi wine grape region of central California

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## Abstract
The Lodi Winegrape District in Central California encompasses a wide range of soils. The presence of both K-fixing (formed in granitic alluvium) and non-K fixing soils complicates grape nutrient management, as both K deficiencies and excess K in fruit are a concern of grape growers. To identify regions within this district that have similar nutrient-management needs, we have developed a soil-landscape model based on soil survey information. Our current revised model identifies six regions within the district with presumed relationships between soil properties and potassium-supplying ability. Region 1 has weakly developed, clay-rich soils in basin alluvium; region 2A (granitic alluvium) and 2B (non-granitic alluvium) have weakly developed, coarser-textured soils on recent alluvial fans, flood plains and stream terraces; region 3 has moderately developed soils on low terraces derived from granitic alluvium; region 4 has highly developed soils on high terraces derived from mixed alluvium; and region 5 has weakly developed soils formed on undulating volcanic terrain. Field and laboratory studies of soils in these regions show that our model is reasonable in concept, but that it must be fine-tuned to account for differing degrees of soil variability within each region in order to make realistic nutrient-management predictions.

## Key Words
Potassium, vermiculite, wine grapes, K fixation, geomorphology, nutrients.

## Introduction
In the Lodi Winegrape District (38.3° N, 121.2° W) in the northern San Joaquin and lower Sacramento Valleys of California, about 32,000 hectares of grapes (*Vitis vinifera*) are cultivated by some 800 growers. The wide range of soil properties, wine grape varieties, and rootstocks in the district make the development of nutrient management recommendations difficult.

In particular, procedures for diagnosing the need for potassium (K) fertilizer are not well developed in the district. K deficiency is the most common nutrient disorder in grape production worldwide and in the district (25% of the vineyards in a 2006 district grower survey). On the other hand, excess K concentrations in fruit can be detrimental to wine quality (Mpelasoka *et al.* 2003). Rootstocks differ greatly in ability to explore the soil and take up K (Lambert *et al.* 2008). Knowledge of soil K relations is important where both K deficiencies and excess K in fruit are to be avoided.

We have observed a very wide range in K fixation capacity (from nil to >10 mmol K/kg soil) and exchangeable K levels in soils collected from vineyards in the Lodi district, reflecting differences in mineralogy. Soils of the east side of the San Joaquin Valley formed from alluvium that accumulated over thousands to millions of years from erosion of the Sierra Nevada. Alluvium has come from metamorphosed sedimentary rock, metamorphosed volcanic rock, volcanic rock, and granite. The lithology and age of parent materials in which the soils formed have changed over time, resulting in a variety of soil mineral assemblages. The Lodi district's soils fall into a systematic spatial pattern: the youngest materials are generally on the west side, the oldest are generally on the east side, and materials of intermediate age are in the center. Moderately weathered soils formed from granitic alluvium contain vermiculite and possibly other K-fixing clay minerals.

K fixation in soils can be inferred from soil survey information. Maps of K fixation and related properties may be useful in selecting wine grape rootstocks and varieties, establishing plant tissue or soil sampling zones within vineyards, and for delineating management zones within vineyards. Management zones could also be used in designing site-specific K fertilizer applications.

In our initial model (O'Geen *et al.* 2008), we grouped the district soils into five categories or "soil regions" based on texture, likely mineralogy, and landscape position. This model proved only partially satisfactory, and recently, we have split one of the five categories to reflect differences in mineralogy of alluvium from the three most important rivers in the district that are responsible for transporting sediment from the Sierra Nevada and its foothills toward the west. In this paper, we summarize the revised model with six soil categories.

**Methods**

The Lodi Winegrape District has a Mediterranean climate with average annual precipitation of 330-470 mm. During 2006-2009, we collected soil samples from 36 commercial winegrape vineyards in the district. Most of the vineyards had been prepared for planting with deep tillage, typically by "ripping" to depths of 60-90 cm. All sampled vineyards are irrigated by above-ground drip systems, and most of the fertilizer, including any K applied, is applied through the irrigation system. Sampling pits and auger holes were positioned midway between vine rows (2.5-3.6 m spacing). We avoided vineyards that were reported by growers to have received high rates of K fertilizer, and we excluded from analysis samples with >200 mg $NH_4OAc$-extractable K/kg soil. A total of 717 individual samples from 141 pits and auger holes were collected. Pits were sampled by horizon, and auger samples were collected in 20-cm depth increments. Soils were air dried and subsamples were screened to pass 2 mm. Cations were measured in 1M neutral $NH_4$-acetate extracts. K fixation was determined by shaking samples for 1 hr in 2 mM KCl followed by extraction with 1M $NH_4Cl$ (Murashkina *et al.* 2007a). Particle size distribution was determined by pipette method and sieve fractionation for sand. Clay and silt fractions were subjected to x-ray diffraction with cation saturation, glycerol, and heating. Grain counts were made on samples of the very fine sand fraction.

**Results**

Representative profiles and comments are shown for all six model regions, with exchangeable K (XK), K fixation (K fix), and particle size values presented. Grain counts (data not shown) indicated presence of vermiculite in the very fine sand fraction of the K-fixing samples shown here. This is consistent with earlier findings in the San Joaquin Valley that clay-sized material may be smectitic (non-K fixing) in the same soil having silt- and very fine sand-sized vermiculite (Murashkina *et al.* 2007b).

*Region 1)* Fine-textured basin alluvium with moderate levels of K-rich weatherable levels and little or no K fixation. The profile is mapped as a Stockton soil, Xeric Epiaquert. These soils tend to be poorly drained and, depending on the source of the parent materials, may have high K fixation potential in the subsoil.

| Horizon | Depth | X - K mg/kg soil | K - fix mg/kg soil | Clay % | Silt % | Sand % |
|---|---|---|---|---|---|---|
| Ap | 0-13 | 317 | 0 | 44 | 37 | 19 |
| Bt1 | 13-38 | 97 | 96 | 47 | 37 | 16 |
| Btss | 38-60 | 87 | 277 | 46 | 39 | 15 |
| C | 60-110 | 45 | 467 | 30 | 38 | 32 |

*Region 2A)* Low-relief alluvial fans, stream terraces and flood plains. Soils formed from granitic alluvium with coarse-loamy or finer texture. Examples are Sailboat and Columbia soil, with low cation exchange capacity, low water-holding capacity, and moderate to high K fixation. The profile shown is mapped as an Aquic Xerofluvent.

| Horizon | Depth | X - K mg/kg soil | K - fix mg/kg soil | Clay % | Silt % | Sand % |
|---|---|---|---|---|---|---|
| Ap1 | 0 - 7 | 286 | 0 | 9 | 60 | 31 |
| Ap2 | 7 - 41 | 67 | 242 | 12 | 58 | 30 |
| C1 | 41 - 61 | 49 | 348 | 16 | 61 | 23 |
| C2 | 61 - 96 | 45 | 248 | 6 | 23 | 71 |
| C3 | 96 - 135 | 36 | 318 | 6 | 45 | 49 |
| Ab | 135 - 150 | 61 | 327 | 25 | 69 | 6 |

*Region 2B)* Low relief alluvial fans, stream terraces and flood plains. Formed mainly on metasedimentary alluvium found in the Calaveras River and possibly Mokelumne River soils. Coarse textured. Do not fix K or fix K only in deepest depths. Examples are Tujunga and Tokay soils. Some fine-textured soils are included such as the profile mapped as the Archerdale, a Pachic Haploxeroll.

| Horizon | Depth | X - K mg/kg soil | K - fix mg/kg soil | Clay % | Silt % | Sand % |
|---|---|---|---|---|---|---|
| Ap1 | 0 - 2 | 683 | 0 | 46 | 40 | 14 |
| Ap2 | 9-Feb | 187 | 0 | 48 | 40 | 12 |
| Ap3 | 28-Sep | 113 | 19 | 49 | 39 | 12 |
| BA | 28 - 46 | 123 | 42 | 49 | 40 | 11 |
| Bt | 46 - 75 | 135 | 18 | 55 | 35 | 10 |
| Btk | 75 - 110 | 149 | 24 | 53 | 37 | 10 |
| 2BCk | 110 - 135 | 119 | 289 | 27 | 65 | 8 |
| 2Bqm | 135 - 170 | 96 | 347 | 28 | 60 | 12 |

*Region 3)* Undulating, low fan terraces. Highly weathered soils on low, moderately old terraces. Subsoil layers contain K-fixing minerals; however this may depend on the source of parent minerals. Examples are the San Joaquin, Bruella, Cometa, and Montpellier soils. These initially had shallow rootzones with low water-holding capacity, but deep tillage has improved them. This profile is mapped as San Joaquin, Abruptic Durixeralf.

| Horizon | Depth | X - K mg/kg soil | K - fix mg/kg soil | Clay % | Silt % | Sand % |
|---|---|---|---|---|---|---|
| Ap1 | 0 - 12 | 65 | 235 | 20 | 26 | 54 |
| Ap2 | 30-Dec | 45 | 377 | 20 | 24 | 56 |
| Bt1 | 30 - 44 | 32 | 259 | 15 | 32 | 53 |
| Bt2 | 44 - 60 | 34 | 215 | 17 | 31 | 52 |
| Bt3 | 60 - 79 | 67 | 208 | 37 | 22 | 41 |
| Bt4 | 79 - 100 | 53 | 231 | 37 | 19 | 44 |

*Region 4)* Rolling, dissected fan terraces. Highly weathered soils on high, old fan remnants. The Redding soil (Abruptic Durixeralf) is an example. These soils also have hardpans and have usually been improved by ripping. They typically do not fix K; however some Redding soils do fix K.

| Horizon | Depth | X - K mg/kg soil | K - fix mg/kg soil | Clay % | Silt % | Sand % |
|---|---|---|---|---|---|---|
| Summit | | | | | | |
| Ap1 | 0-16 | 384 | 0 | 29 | 33 | 38 |
| Ap2 | 16-60 | 213 | 0 | 34 | 30 | 36 |
| BAt | 60-97 | 110 | 0 | 26 | 16 | 59 |
| Bt1 | 97-107 | 50 | 0 | 48 | 20 | 31 |
| Bt2 | 107-145 | 68 | 0 | 43 | 23 | 34 |
| Btqm | 145-155 | 44 | 0 | 10 | 13 | 77 |
| BCt | 155-180 | 49 | 0 | 23 | 23 | 54 |
| Backslope | | | | | | |
| Ap | 0 - 21 | 52 | 9 | 21 | 27 | 52 |
| Bt | 21 - 45 | 73 | 0 | 53 | 17 | 30 |
| Btq1 | 45 - 60 | 118 | 85 | 12 | 10 | 78 |
| Btq2 | 60 - 75 | 33 | 159 | 19 | 20 | 61 |
| Btqm | 75 - 100 | 45 | 146 | 15 | 16 | 69 |

*Region 5)* Undulating volcanic terrain of the eastern portion of the district. Pentz, Pardee, and Keys soils are examples. They have low available water holding capacity and are shallow to bedrock. They typically do not fix K. This profile is mapped as Pentz, Ultic Haploxeroll.

| Horizon | Depth | X - K<br>mg/kg soil | K - fix<br>mg/kg soil | Clay<br>% | Silt<br>% | Sand<br>% |
|---|---|---|---|---|---|---|
| Ap | 0-23 | 448 | 0 | 17 | 10 | 73 |
| Bw | 23-60 | 352 | 0 | 18 | 8 | 75 |
| C | 60-80 | 264 | 0 | 16 | 6 | 79 |
| Cr | 80-120 | 149 | 0 | 11 | 10 | 78 |

**Summary and Conclusions**

Our revised model predicts well the observed K fixation in Region 3 and lack of soil K fixation in Region 5. Region 2 K fixation is modeled realistically when granitic and non-granitic alluvium are separated (2A vs. 2B); but this situation is complicated somewhat by stratigraphy. Region 1 (fine texture and smectitic mineralogy) is not extensively planted to wine grapes in the district, and the modeling of K fixation is complicated by distribution of older underlying strata. Region 4 is still inadequately modeled, and more research is needed to understand stratigraphy and hillslope processes. A problem with modeling soil properties in district vineyards is that most vineyard soil profiles have been disturbed by subsoil tillage during land preparation before planting. However, in many cases in pits and auger sampling, we encountered duripans and argillic horizons as expected from the soil survey.

Optimizing the timing of K fertilizer applications to prevent undesired deficiencies while avoiding excessive uptake of K by fruit is a challenge. Our studies have shown that a significant area of vineyard soils in the district fix K, although usually not in the top 15-30 cm. The significance of K fixation for management of vine K nutrition has not been established. Irrigation and application of K fertilizer through the drip irrigation system, rootstock vigor, and fertilizer K rate and timing may interact with soil properties to control K uptake by vines.

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