Potassium: Use and Application and Availability in Soils
Phoebe Gordon, Ph.D
University of California, Cooperative Extension
Madera and Merced Counties

Plant Physiology of Potassium
- Activator of enzymes
- Involved in stomatal function
- Helps to regulate ion balances in cells
- Involved in sugar synthesis
- Increases oil content in pistachio fruit
- Contributes to cold hardiness

Potassium Deficiency
- Leaves become pale during summer
- Leaflets fold upward and curl in
- Yellow tips that progress inward; tissue eventually browns
- Slow growth
- Small leaves
- Low yield
Physiology of Potassium

- Most potassium needed by bearing trees is to supply the fruit
- Most of K uptake in bearing trees is for kernel fill
- 29 lbs K2O removed per 1000 lbs of nuts removed
- 27 lbs K2O needed to supply tree growth

Leaf analysis levels

<table>
<thead>
<tr>
<th>Critical Value</th>
<th>Adequate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6%</td>
<td>1.8 – 2.2%</td>
</tr>
</tbody>
</table>

Potassium in Soils

- Potassium is immobile in soils because it is loosely bound onto negatively charged clay and organic matter
- Clay and organic matter forms the "CEC"
- The size of your CEC is dependent on how much clay and organic matter you have
Cation Exchange Capacity

- The CEC acts as a reservoir for positively charged ions
  - K, Ca, Mg? Good!
  - Na: bad!
- When thinking about cations, you also must be thinking about the CEC size
- Lab tests will give you ppm K, %K on the CEC, or both
  - %K is usually more useful, since it gives you an idea of how much of the CEC is taken up by K
- Rough rule of thumb: soils are “deficient” in K with either less than 200 ppm OR 2% of the CEC
- It’s best to just apply what has been lost via crop removal

Potassium Fixing Soils

- Ammonium acetate test not appropriate for soils that fix K
- Fixed K becomes available over time
  - Rate can change based on soil
- Do not add K fertilizers far in advance of tree needs in K fixing soils

Cation antagonism

- Carrier proteins for nutrient uptake is not always specific to an ion
  - Worse for cations of similar charge and/or size
    - Example: K⁺ and Na⁺, K⁺ and NH₄⁺
    - Also Ca²⁺, Mg²⁺, K⁺
    - Cl⁻ and NO₃⁻
- But you can have ion antagonism in extreme cases
  - E.g. Ca deficiency in high Mg soils such as serpentine
  - Depression of one cation with application of fertilizer containing another
- Not much evidence that there is an ideal cation ‘ratio’ that is perfect across all sites
  - Maintaining this may be expensive
Soil Tests

- Ammonium Acetate extraction:
  - Supposed to measure available K
  - Not great at estimating available K in fixing soils
- Water soluble (saturated paste extraction):
  - Only removes water soluble K
  - No sufficiency standards developed
- AA tests will tell you ppm in soil
- Labs will calculate %K for you
- CEC in most cases is estimated
  - Can be VERY inaccurate if recently applied gypsum, lime and sampler took no steps to exclude it

Potassium Fertilizers

- K₂O: Potassium Oxide, known as potash. Not actually in fertilizers! 83%K

<table>
<thead>
<tr>
<th>Source</th>
<th>Formula</th>
<th>% K₂O</th>
<th>Solubility @ 20°C (grams/Liter)</th>
<th>% K₂O in a saturated solution</th>
<th>Cost per lb K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium Chloride</td>
<td>KCl</td>
<td>63</td>
<td>255</td>
<td>18.1</td>
<td>$0.41</td>
</tr>
<tr>
<td>Potassium Sulfate</td>
<td>K₂SO₄</td>
<td>54</td>
<td>111</td>
<td>5.4</td>
<td>$0.67</td>
</tr>
<tr>
<td>Potassium Nitrate</td>
<td>KNO₃</td>
<td>47</td>
<td>209</td>
<td>11.2</td>
<td>$1.33</td>
</tr>
<tr>
<td>Potassium Thiosulfate</td>
<td>K₂S₂O₃</td>
<td>25</td>
<td>complete</td>
<td>25</td>
<td>$1.38</td>
</tr>
</tbody>
</table>

Solubility data may differ by manufacturer, or if the amount of impurities is high

Costs are quotes from 2019, and actual prices may differ

Previous Research

- Patrick Brown, Brent Holtz, and Quipeng Zeng looked at K fertilization in a mature pistachio orchard in a San Joaquin series soil
- They added 0, 100, 200, 300 lbs of K/acre
- Looked at three different sources: K₂SO₄, KCl, KNO₃
- Trial lasted 3 years, with K split into 4 applications per year
Zeng, Brown, and Holtz.

- No difference between K source
- Yield maximized at 200 lbs/year

Solubility

- Tells you the maximum amount of a salt that will dissolve in pure water at a given temperature
- Solubility of potassium fertilizer does not change how potassium ultimately behaves in the soil
  - But there are tricks that can reduce the importance of fixation
- Easily soluble fertilizer applied early in the season (or last year) in potassium fixing soils can still be fixed
- The key to potassium fertilizer application is applying a product that works for you in a way that is appropriate for your soil

Solubility of Fertilizers and Application

- Solubility can become be an issue in fertigation, particularly if you like to apply all of your K over a small number of applications
- Higher soluble fertilizers are more efficient lb/lb, (You can deliver the same amount of dissolved K₂O in less water than lower soluble fertilizers) but there are no differences in ‘available’ potassium
Fertigation vs Banding?

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No K</td>
<td>2152</td>
<td>2707</td>
<td>2956</td>
<td>2956</td>
</tr>
<tr>
<td>0.38 kg SOP</td>
<td>2382</td>
<td>2719</td>
<td>2916</td>
<td>3313</td>
</tr>
<tr>
<td>0.75 kg SOP</td>
<td>2305</td>
<td>2707</td>
<td>2792</td>
<td>3335</td>
</tr>
<tr>
<td>0.38 kg MKP</td>
<td>2511</td>
<td>2862</td>
<td>2067</td>
<td>3727</td>
</tr>
<tr>
<td>0.38 kg RTS</td>
<td>2545</td>
<td>2687</td>
<td>2828</td>
<td>3053</td>
</tr>
<tr>
<td>0.75 kg SOP banded</td>
<td>2775</td>
<td>2978</td>
<td>2585</td>
<td>3534</td>
</tr>
</tbody>
</table>

- Banded SOP achieved similar yields in year three to fertigated SOP (same rate)
- MKP was (not significantly) best – unknown if this was due to P or something else


Fertigation vs soil application?

<table>
<thead>
<tr>
<th>Soil depth</th>
<th>0 feet from emitter</th>
<th>1 foot from emitter</th>
<th>2 feet from emitter</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4&quot;</td>
<td>2313</td>
<td>213</td>
<td>213</td>
</tr>
<tr>
<td>6-12&quot;</td>
<td>2313</td>
<td>213</td>
<td>213</td>
</tr>
<tr>
<td>12-18&quot;</td>
<td>3204</td>
<td>332</td>
<td>113</td>
</tr>
<tr>
<td>18-24&quot;</td>
<td>3204</td>
<td>332</td>
<td>113</td>
</tr>
<tr>
<td>24-30&quot;</td>
<td>3204</td>
<td>332</td>
<td>113</td>
</tr>
<tr>
<td>30-36&quot;</td>
<td>3204</td>
<td>332</td>
<td>113</td>
</tr>
</tbody>
</table>


Fertilizer Application Strategies

- Banding SOP works in any soil type, as long as it is banded in the wetted zone of your irrigation system
  - Because surface-applied K mostly stays put, fertilizer that can only be dissolved by rain will not be in the root zone
- In K-fixing soils: banding saturates the fixation capacities of a soil, ensuring K is available for uptake
- Fertigation can avoid fixation, but only if it’s applied in season
- Banding can be a great addition to fertigation, especially in non-fixing soils
When to fertilize

- If your trees are very deficient (< 1.6% K):
  - Apply high rates and monitor leaf levels closely
  - 100-200 lbs K₂O/acre overcame deficiencies in a loam soil
- If your trees are not deficient, apply to replace what’s been removed
  - It’s always better to maintain levels rather than remedy deficient trees

Maintenance fertilization rates

<table>
<thead>
<tr>
<th>Yield (kernel lbs/acre)</th>
<th>K₂O/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>55</td>
</tr>
<tr>
<td>2000</td>
<td>84</td>
</tr>
<tr>
<td>3000</td>
<td>113</td>
</tr>
<tr>
<td>4000</td>
<td>142</td>
</tr>
<tr>
<td>5000</td>
<td>171</td>
</tr>
</tbody>
</table>

29 lbs K₂O removed with every 1000 lbs kernels
27 lbs K₂O needed for tree growth

When to fertilize

- Non-potassium fixing soils
  - Apply whenever you like, however you like
  - Band? Make sure it’s in the wetted zone
- Potassium fixing soils
  - Fertigation: start a little before trees need it (nut fill/Stage 3), split applications between April-August
  - If soil applying, BAND to overcome fixation, and ensure the fertilizer is in the wetted zone
  - You can do both!
Thank you!

pegordon@ucanr.edu  best way to reach me
559-675-7879 ext. 7209
www.growingthevalleypodcast.com
www.sjtandv.com