<table>
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<tr>
<th>Rootstock</th>
<th>N (%)</th>
<th>K (%)</th>
<th>B (ppm)</th>
<th>Ca (%)</th>
<th>Mg (%)</th>
<th>Na (ppm)</th>
<th>Cl (%)</th>
<th>Zn² (ppm)</th>
<th>Mn (ppm)</th>
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<tbody>
<tr>
<td>Nemaguard</td>
<td>2.30a¹</td>
<td>2.76abc</td>
<td>47a</td>
<td>3.84de</td>
<td>0.61d</td>
<td>74abc</td>
<td>0.09a</td>
<td>101a</td>
<td>64cd</td>
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<td>Lovell</td>
<td>2.28a</td>
<td>2.92ab</td>
<td>47a</td>
<td>3.56e</td>
<td>0.61d</td>
<td>75ab</td>
<td>0.08b</td>
<td>112a</td>
<td>69cd</td>
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<td>Guardian</td>
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<td>2.57cd</td>
<td>47a</td>
<td>3.73e</td>
<td>0.70b</td>
<td>69bde</td>
<td>0.08b</td>
<td>96a</td>
<td>57d</td>
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<td>Atlas</td>
<td>2.27a</td>
<td>2.70bc</td>
<td>49a</td>
<td>4.23bc</td>
<td>0.67bc</td>
<td>66cde</td>
<td>0.04c</td>
<td>100a</td>
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<td>Viking</td>
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<td>2.99a</td>
<td>45ab</td>
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<td>0.47e</td>
<td>73abcd</td>
<td>0.04c</td>
<td>106a</td>
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<td>2.27e</td>
<td>42bc</td>
<td>4.78a</td>
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<td>65de</td>
<td>0.03c</td>
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<td>Bright’s</td>
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<td>2.40de</td>
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<td>4.44b</td>
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<td>0.03c</td>
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<td>102b</td>
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<td>Hinsen</td>
<td>2.08b</td>
<td>2.00f</td>
<td>40c</td>
<td>5.03a</td>
<td>0.75a</td>
<td>61e</td>
<td>0.03c</td>
<td>112a</td>
<td>132a</td>
</tr>
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</table>

¹ Different letters within a column indicate significant differences.
Fig. 2. Soil Numbers of Pathogenic Nematodes as Influenced by Rootstock

May, 2004
Potassium Needs and Current Approaches in Almond Production

Roger Duncan
UCCE Pomology & Viticulture Advisor
Stanislaus County
Potassium Nutrition

- Essential for formation of starch
- Essential for translocation of sugars
- Regulates opening and closing of stomata
  - K+ is pumped into guard cells
  - Water moves into guard cells in response to osmotic gradient
  - Guard cells swell, open stomata
Potassium Nutrition

• Promotes root growth
  – produces large, uniformly distributed xylem vessels in root system

• Increases size and quality of fruits and nuts*
Potassium Deficiency Symptoms Include...

- Slow growth
  - leaves become pale
  - leaf size and shoot growth are reduced

- The tip and subterminal margins of leaves become necrotic
  - leaf tip sometimes curls upward
  - Vikings “prow”
Severe K⁺ Deficiency in Almond
How do we know if we need to apply potassium fertilizer?

LEAF ANALYSES!
The University “Party Line”

- Deficient: below 1% K
- Adequate: over 1.4% K

* based on leaves sampled from non-fruiting spurs in July

**What???

***Numbers were developed many decades ago based on foliar symptoms - not yield

****Growers are no longer satisfied with yields less than 2000 lb per acre
• Word on the street says $K^+$ values should be 2% or higher

• IS THIS TRUE???
Comparison of Leaf Potassium Values vs. Nonpareil Yield
A survey of 10 Stanislaus County orchards, 1997

• Survey of 10 “comparable” orchards
  – Nonpareil variety
  – Similar age (not too old, not too young, not too sick)
Comparison of Leaf Potassium Values vs. Nonpareil Yield
A survey of 10 Stanislaus County orchards

- Leaves sampled from 15-18 consecutive, “representative” trees in each orchard on July 25, 1997

- Submitted to A & L Labs for analyses

- Harvested and determined yield for same 15-18 trees in each orchard.
Comparison of Leaf Potassium Values vs. Nonpareil Yield
A survey of 10 Stanislaus County orchards, 1997

Leaf K+ in July Samples vs. Meat Pounds per Acre
Comparison of Leaf Potassium Values vs. Kernel size
A survey of 10 Stanislaus County orchards, 1997

![Graph showing the comparison of Leaf Potassium Values vs. Kernel size. The x-axis represents Leaf K+ in July Samples, ranging from 0 to 3. The y-axis represents the Mass of 100 kernels (g), ranging from 100 to 150. The graph includes several data points represented by diamonds.](image)
Summary

- Almost all orchards above published 1.4% K
- No apparent relationship between leaf K values and yield
- No relationship between leaf K and kernel size
- Differences may be masked by differences in other cultural practices
Potassium Trial 1998-2002
Salida, CA
Weinbaum, Duncan, Reidel

• Purpose: to reassess critical K leaf levels
  
  – determine at which point almond yields are no longer responsive to added K

  – Determine how K deficiency leads to yield reduction (i.e. flower number, percent fruit set, fruit / kernel size)
Potassium Trial 1998-2002
Salida, CA

• A range of tree K status was established through differential fertilization over 4 years
  – 0, 200, 500 or 800 lb. $\text{K}_2\text{SO}_4$ applied annually

• Each year we monitored leaf K, spur survival, spur renewal, shoot elongation & yields
Leaf Potassium Dynamics During Four Years of Differential Fertilization with Potassium Sulfate

- July Leaf K (%)
  - 0 lb
  - 200 lb
  - 500 lb
  - 800 lb

Year
- 1998
- 1999
- 2000
- 2001
Yield of Nonpareil Almond Trees After Four Years of Differential Potassium Fertilizer Rates 2002

Pounds of sulfate of potash applied per acre each year.

Meat lb per acre

0 500 1000 1500 2000 2500 3000 3500

0 200 500 800

0 200 500 800

A A B AB

Pounds of sulfate of potash applied per acre each year.
2002 Almond Yields as Related to Average Leaf K+ Values From 1998-2002

\[ R^2 = 0.30 \]

\[ P = 0.02 \]
2002 Almond Yields as Related to Average Leaf K+ Values From 1998-2002

$R^2 = 0.30$

$P = 0.02$
Relation of 2002 Almond Yields to 1999 - 2001 Leaf K⁺ Values

Yield vs leaf K⁺ of 1.4% or less:
- \( P = 0.048 \)
- \( R^2 = 0.40 \)

Yield vs leaf K⁺ of more than 1.4%:
- \( P = \text{NS} \)
- \( R^2 = -0.18 \)
Summary of Results of 5 Year Trial

- 200 lb of annually applied sulfate of potash barely maintained K leaf levels
- It took 4 years of 800 lb K$_2$SO$_4$ applications to raise leaf levels from 1.2% to 1.9 %
- Unfertilized trees fell from 1.2% to 0.6%
- Leaf symptoms not obvious until 1% K or less
Summary of Results of 5 Year Trial

• It took three years to significantly affect yield

• Inadequate K did not affect
  – percent fruit set
  – kernel size
Summary of Results of 5 Year Trial

• Inadequate potassium reduced yield because:
  – Mortality of fruiting spurs was increased
  – Flowering of surviving spurs was reduced
  – Shoot growth and spur renewal was reduced
Summary of Results of 5 Year Trial

Data suggest that 1.4% $K^+$ in July sampled leaves is pretty close to correct economic threshold.
Now that we have established that the $K^+$ critical level is 1.4%, what is the best way to fertilize?
Annual Potassium Needs

• Almonds
  – nitrogen \(\sim 200\text{ lb. N / acre}\)
  – potassium \(\sim 250\text{ lb. }K_2O / \text{acre}\)

• Peaches
  – nitrogen \(\sim 100\text{ lb. N / acre}\)
  – potassium \(\sim 125\text{ lb. }K_2O / \text{acre}\)
Annual Potassium Needs

• Although peaches and almonds use more potassium than nitrogen each year, do we need to add more potassium than nitrogen each year to maintain sufficient levels??

• Not always (not usually??)
Annual Potassium Needs

• Depends on:
  – soil parent material
  – soil texture (leaching)
  – irrigation system
  – amount of potassium carried away each year
Potassium Nutrition

• Soils may contain 900 - 1500 lb K₂O / 1000 ft² (1 foot deep)
  – 90-98% in primary material (unavailable)
  – 1-10% trapped in expanding lattice clays
  – Only 1-2% of total soil K⁺ is contained in the soil solution and on exchange sites & is readily available to plants
  – Steady release and low leaching make potassium less likely to be deficient (compared to N)
Potassium Nutrition

• Fertilizers are expressed as % K$_2$O
• Taken up by plant as K$^+$
• Remains in the plant as K$^+$
Potassium Fertilizers Should be Applied in a Concentrated Band

- Soil particles are negatively (-) charged
- $\text{K}^+$ ions are bound tightly to soil particles
- Soil particles must be saturated with $\text{K}^+$ before it is available in soil solution

Is it cost efficient to apply a “Tree & Vine” fertilizer (i.e. 15-15-15)?
Cost to Supply 250 lb K₂O Using Various K Fertilizers

- **Muriate of potash (KCl): 60-63% K₂O**
  - 400 lb KCl @ $185 / ton = $38 / acre

- **Sulfate of potash (K₂SO₄) ~ 52% K₂O**
  - 480 lb K₂SO₄ @ $270 / ton = $65 / acre

- **Potassium thio sulfate (0-0-25-17)**
  - 1000 lb @ $270 / ton = $135 / acre

- **Liquid K₂SO₄ (1-0-8-2.5)**
  - 3125 lb @ $85 / ton = $133 / acre
One last K Trial

- Experiment compared surface banded K2SO4 with injected K sources:
  - potassium sulfate
  - potassium chloride
  - potassium thiosulfate
  - mono-potassium sulfate

- Three irrigation systems
  - microsprinklers
  - double-lined drip
  - single-lined drip
# Yield & Leaf K Values Related to Potassium Fertilizer Formulation

**Single line drip**

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<tbody>
<tr>
<td>No K</td>
<td>1.18 d</td>
<td>2449 ab</td>
<td>1.09 d</td>
<td>2383 c</td>
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<tr>
<td>1 lb K₂O (K₂SO₄)</td>
<td>1.78 b</td>
<td>2469 ab</td>
<td>1.73 ab</td>
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<tr>
<td>2 lb K₂O (K₂SO₄)</td>
<td>1.87 ab</td>
<td>2494 ab</td>
<td>1.94 a</td>
<td>2607 bc</td>
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<td>1 lb K₂O (MKP)</td>
<td>1.77 b</td>
<td>2786 a</td>
<td>1.37 cd</td>
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<tr>
<td>1 lb K₂O (KTS)</td>
<td>1.73 bc</td>
<td>2307 ab</td>
<td>1.71 ab</td>
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<td>2 lb K₂O (K₂SO₄ band)</td>
<td>1.48 c</td>
<td>2102 b</td>
<td>1.53 bc</td>
<td>2431 c</td>
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Yield & Leaf K Values Related to Potassium Fertilizer Formulation

**Microsprinklers**

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</thead>
<tbody>
<tr>
<td>No K</td>
<td>1.26</td>
<td>f</td>
<td>1.38</td>
<td>f</td>
</tr>
<tr>
<td>1 lb K₂O (K₂SO₄)</td>
<td>1.71</td>
<td>e</td>
<td>1.87</td>
<td>e</td>
</tr>
<tr>
<td>2 lb K₂O (K₂SO₄)</td>
<td>2.33</td>
<td>bc</td>
<td>2.63</td>
<td>bc</td>
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<tr>
<td>1 lb K₂O (MKP)</td>
<td>2.06</td>
<td>cde</td>
<td>2.04</td>
<td>de</td>
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<tr>
<td>1 lb K₂O (KTS)</td>
<td>1.81</td>
<td>de</td>
<td>1.91</td>
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<tr>
<td>2 lb K₂O (K₂SO₄ band)</td>
<td>2.11</td>
<td>cd</td>
<td>2.07</td>
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Bottom Line for Nickels Field Trial

- Injected mono-potassium phosphate tended to give the highest yields, followed by injected $\text{K}_2\text{SO}_4$
- Banded $\text{K}_2\text{SO}_4$ increased leaf K and yield substantially in microsprinkler and double-lined drip plots, but not in single-lined drip plots
- There was no relationship between K fertilization and kernel size
Drip hose too far from K application
Drip hose needs to be over K fertilizer
Roger’s Recommendations

1.4% leaf K is probably a pretty accurate critical value

I don’t argue with any grower who wants 2-3% K - its their money!

I don’t believe grower testimonials that higher K = higher yields
Roger’s Recommendations

Banding dry K fertilizers is probably best for flood irrigation, maybe micros

Using KCl instead of K$_2$SO$_4$ is probably OK in flood-irrigated, sandy locations (monitor Cl)

Banding is not efficient in drip-irrigated orchards - better to inject
Correcting K+ deficiency takes a long time with substantial loss in yield

By the time you see deficiency symptoms, trees are already deficient and yield is lost

Monitor with leaf samples - maintain an ‘adequate’ cushion above 1.4% K