Potassium Needs and Current Approaches in Almond Production

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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

Current K threshold is 1.4%
Comparison of Leaf Potassium Values vs. Kernel size
A survey of 10 Stanislaus County orchards, 1997

Leaf K+ in July Samples

Mass of 100 kernels (g)
Summary

• Almost all orchards were above the currently recommended 1.4% K threshold.
• No apparent relationship between leaf K values and yield.
• No relationship between leaf K and kernel size.
• Differences may be masked by other contributing factors (differences in other cultural practices, etc.).
• OR – Increasing potassium levels above 1.4% may not lead to higher yields (i.e., the established critical level may be correct!)
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. K₂SO₄ 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
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

B AB A A

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

R² = 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
- R² = 0.40

**Yield vs leaf K⁺ of more than 1.4%:**
- P = NS
- R² = -0.18

Average Leaf Potassium values from 1999-2001
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 $\text{K}_2\text{SO}_4$ 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 the 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 ~ 200 lb. N / acre
  – potassium ~ 250 lb. K₂O / acre

• Peaches
  – nitrogen ~ 100 lb. N / acre
  – potassium ~ 125 lb. K₂O / 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 % K₂O
- 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
- $K^+$ ions are bound tightly to soil particles
- Soil particles must be saturated with $K^+$ before it is available in soil solution

Is it cost efficient to apply a “Tree & Vine” fertilizer (i.e. 15-15-15)?

• 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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<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 / tree (K₂SO₄)</td>
<td>1.78 b</td>
<td>2469 ab</td>
<td>1.73 ab</td>
<td>2944 abc</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>
<td>3280 a</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>
<td>2741 abc</td>
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<tr>
<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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<tbody>
<tr>
<td>No K</td>
<td>1.26 f</td>
<td>2645 abc</td>
<td>1.38 f</td>
<td>2332 e</td>
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<tr>
<td>1 lb K2O (K2SO4)</td>
<td>1.71 e</td>
<td>2916 abc</td>
<td>1.87 e</td>
<td>2725 cde</td>
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<tr>
<td>2 lb K2O (K2SO4)</td>
<td>2.33 bc</td>
<td>2698 abc</td>
<td>2.63 bc</td>
<td>3054 abcd</td>
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<td>1 lb K2O (MKP)</td>
<td>2.06 cde</td>
<td>2952 ab</td>
<td>2.04 de</td>
<td>3475 ab</td>
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<td>1 lb K2O (KTS)</td>
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<td>3207 a</td>
<td>1.91 e</td>
<td>2500 de</td>
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<tr>
<td>2 lb K2O (K2SO4 band)</td>
<td>2.11 cd</td>
<td>2325 c</td>
<td>2.07 de</td>
<td>3456 ab</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 - it's their money!

I am skeptical of 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