Potassium Nitrate as a Superior K Source for Fertigated California Almonds

Harmen Tjalling HOLWERDA
PNA Agronomy Committee
1. Principles of proper K-source selection

2. PNA trial about various K-sources in fertigated California almonds

3. PNA website content
Overview main K-sources - Differences are decided for by the counterion

<table>
<thead>
<tr>
<th>Name</th>
<th>In short</th>
<th>Formula</th>
<th>Contents (minimum %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium nitrate</td>
<td>PN</td>
<td>KNO$_3$</td>
<td>N: 13, K$_2$O: 46</td>
</tr>
<tr>
<td>Potassium sulfate</td>
<td>SOP (Sulfate of Potash)</td>
<td>K$_2$SO$_4$</td>
<td>S: 50, Cl: 17</td>
</tr>
<tr>
<td>Potassium thiosulfate</td>
<td>PTS</td>
<td>K$_2$S$_2$O$_3$</td>
<td>S: 25, Cl: 17</td>
</tr>
<tr>
<td>Potassium chloride</td>
<td>MOP (Muriate of Potash)</td>
<td>KCl</td>
<td>N: 60, Cl: 47</td>
</tr>
</tbody>
</table>
Substitution of KNO$_3$ by alternative K and N sources

<table>
<thead>
<tr>
<th>Name</th>
<th>In short</th>
<th>Formula</th>
<th>N-source</th>
<th>Derived from</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium nitrate</td>
<td>PN</td>
<td>KNO$_3$</td>
<td>NO$_3^-$</td>
<td>Potassium nitrate</td>
</tr>
<tr>
<td>Potassium sulfate</td>
<td>SOP (Sulfate of Potash)</td>
<td>K$_2$SO$_4$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium thiosulfate</td>
<td>PTS</td>
<td>K$_2$S$_2$O$_3$</td>
<td>NH$_4^+$</td>
<td>Urea, UAN, ammonium sulfate</td>
</tr>
<tr>
<td>Potassium chloride</td>
<td>MOP (Muriate of Potash)</td>
<td>KCl</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Right K-fertilizer selection

- **Chloride-sensitive crops** - avoid Cl-containing fertilizers (KCl)

- **Salinity-sensitive crops** – avoid excess S (and Cl).
  Limit the S supply to demand of crops, grown in semi-arid/arid areas or under saline growing conditions, and when using irrigation water of poor quality.

- **Maintain the right N-balance**: 75-90% N-nitrate & 25-10% N-ammonium
  With nitrate - cation synergism (K, Ca, Mg); anion antagonism (Cl)

- **KNO₃** - PREFERRED K-SOURCE TO COMBAT SOIL SALINITY
California situation
Excess sulfate = salinity problems

• Lack of winter rains and lack of low EC irrigation water to leach the salts out of the rooting zone will result in a continuous salt accumulation in the rooting zone.

• Almonds are sensitive to saline soils:
  10% drop in potential yield per EC\textsubscript{sse} increase of 0,5 mS/cm!

<table>
<thead>
<tr>
<th>EC saturated soil extract</th>
<th>Almond Yield Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>1,5</td>
</tr>
</tbody>
</table>

• Excess sulfate in the rooting zone can also cause a Ca-sulfate fixation to occur in the rooting zone, which will impair Ca uptake by the tree.

*Ayers and Westcot (1989):* Critical soil salinity EC\textsubscript{e} for various potential yield levels in horticultural crops.
Partners

• Univ. of California, Davis (Prof Patrick Brown)
• World’s largest almond and pistachio grower and processor
• PNA (300,000 US$)

Trial in fertigated almond from 2011-2014 (4 years)
Trial in fertigated almond from 2011-2014 (4 years)

Treatments
• 8 fertilizer treatments with different K-sources (KNO3, PTS, SOP, KCl)
• 2 fertigation frequencies (4 vs 22 events)
• 2 irrigation methods (Fan Jet microsprinkler vs drip irrigation)

Statistical Design
• 8 Fertilizer tr.* 3 variety_irrigation system combinations
• Split plot design with 5 replicates; in total 120 plots

<table>
<thead>
<tr>
<th>Example</th>
<th>Block - Fertilizer treatment 1 ; 3 parallel rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot size – 15 trees in</td>
<td>Nonpareil-Fanjet</td>
</tr>
<tr>
<td>a row</td>
<td>Tree 1</td>
</tr>
<tr>
<td></td>
<td>..</td>
</tr>
<tr>
<td></td>
<td>Tree 15</td>
</tr>
<tr>
<td></td>
<td>Monterey-Fanjet</td>
</tr>
<tr>
<td></td>
<td>Tree 1</td>
</tr>
<tr>
<td></td>
<td>..</td>
</tr>
<tr>
<td></td>
<td>Tree 15</td>
</tr>
<tr>
<td></td>
<td>Nonpareil-Drip</td>
</tr>
<tr>
<td></td>
<td>Tree 1</td>
</tr>
<tr>
<td></td>
<td>..</td>
</tr>
<tr>
<td></td>
<td>Tree 15</td>
</tr>
</tbody>
</table>
Almond orchard
Fertigation trial preparation in February 2011
Almond orchard

Fertigation trial preparation in February 2011

- Five Grundfos dosing pumps (150 L/h), new mainlines and manifolds are used to inject the 5 continuous fertigation treatments.
Almond orchard
Fertigation trial preparation in February 2011
Almond orchard
Fertigation trial preparation in February 2011

- 8 hectares of a set of 20 hectares were completely replumbed.
- New submains: 1 for each “continuous feed” treatment.
- In total: 5600 meters of pipe!
Almond orchard
Fertigation trial preparation in February 2011

• Also a replicated comparison of microsprinkler and double-line drip

2 Fan-Jet microsprinklers per tree  double-line drip

Fan Jet Turned off
Almond orchard
Fertilizer application
Winter banding of sulphate of potash (@ 140 kg K/ha = 336 kg SOP/ha)
Pulse fertigation versus continuous fertigation application schedule

- Pulse: 4 fertigation applications per year.
- Continuous: 22 fertigation applications per year.
- Irrigation cycle: 24 hours per application.

<table>
<thead>
<tr>
<th>Month</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10-12</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient mngt (%)</td>
<td>20</td>
<td>30</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Water management (%)</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

Harvesting is done under dry soil conditions.

Post-harvest
Potassium (K) and Nitrogen (N) supplied in the 8 treatments during trial period. Freq: Fertigation frequency (nr of events), C: Continuous fert., P: Pulse fert.

<table>
<thead>
<tr>
<th>Trt</th>
<th>Freq</th>
<th>Total K</th>
<th>SOP Band</th>
<th>SOP Fert*</th>
<th>PTS</th>
<th>KCL</th>
<th>KNO₃</th>
<th>Total N</th>
<th>KNO₃</th>
<th>UAN</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>P (4)</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td>336</td>
<td>336</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No K</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>P (4)</td>
<td>224</td>
<td>140</td>
<td></td>
<td>84</td>
<td></td>
<td></td>
<td>336</td>
<td>336</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Growers Practice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>P (4)</td>
<td>224</td>
<td>140</td>
<td></td>
<td></td>
<td></td>
<td>84</td>
<td>336</td>
<td>30</td>
<td>306</td>
</tr>
<tr>
<td>4</td>
<td>C (22)</td>
<td>224</td>
<td></td>
<td>224</td>
<td></td>
<td></td>
<td></td>
<td>336</td>
<td>336</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>C (22)</td>
<td>224</td>
<td>140</td>
<td></td>
<td></td>
<td></td>
<td>84</td>
<td>336</td>
<td>30</td>
<td>306</td>
</tr>
<tr>
<td>6</td>
<td>C (22)</td>
<td>224</td>
<td></td>
<td>224</td>
<td></td>
<td></td>
<td></td>
<td>336</td>
<td>80</td>
<td>256</td>
</tr>
<tr>
<td>7</td>
<td>C (22)</td>
<td>336</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>336</td>
<td>336</td>
<td>119</td>
<td>217</td>
</tr>
<tr>
<td>8</td>
<td>C (22)</td>
<td>336</td>
<td></td>
<td>168</td>
<td>168</td>
<td></td>
<td></td>
<td>336</td>
<td>60</td>
<td>276</td>
</tr>
</tbody>
</table>

* dissolved in gypsum mixer
Harvesting
Almond shaking
Harvesting
Almond raking
Harvesting
Almond separation
Harvesting
Almond harvester
Harvest

Almond subsample collector (bucket)
Results
Cumulative yield 2012-2014
Fan Jet microsprinkler

Economics

Kernel (edible part)
@ 2.75 US$/lb = 6 US$/kg

Gross income increase T5-T2:
yearly average 3.000 US$/ha

Calculation
1.500 kg/ha/3 yrs * 6 US$/kg = 9.000 US$/ha/3 years ➔
3.000 US$/ha/year

Columns labeled with the same letter are not significantly different (LSD, 10%).
Cumulative yield 2012-2014
Drip irrigation

T2: banded SOP + fertig PTS; 4X (grower’s practice)
T3: banded SOP + fertig PN; 4X
T4: only fertig SOP; 22X
T5: banded SOP + fertig PN; 22 X

Columns labeled with the same letter are not significantly different (LSD, 10%).
Significant increase in nitrogen recovery using Fanjet continuous vs Fanjet pulse fertigation (only analyzed in year 2013)

• Consequence of both:
  – higher nitrogen content in the harvested fruit, as well as
  – higher yields
Significant increase in nitrogen recovery using Fanjet continuous vs Fanjet pulse fertigation (only analyzed in the year 2013)

<table>
<thead>
<tr>
<th>Method</th>
<th>Nitrogen Export (kg N/ha)</th>
<th>N-recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drip Pulse</td>
<td>252</td>
<td>75 %</td>
</tr>
<tr>
<td>Drip Continuous</td>
<td>235</td>
<td>70 %</td>
</tr>
<tr>
<td>Fanjet Pulse</td>
<td>246</td>
<td>73 %</td>
</tr>
<tr>
<td>Fanjet Continuous</td>
<td>314</td>
<td>93 %</td>
</tr>
</tbody>
</table>

Nitrogen export (kg N/ha) and N-recovery, based on fertilizer N input of 336 kg N/ha

Identical K input: banded SOP (336 kg/ha) + fertigated PN (220 kg/ha)

Nitrogen recovery is the product of total fruit nitrogen in all fruit parts (hull, shell, kernel) multiplied by yield.
Main conclusions ("4 R” Principles)

1. **Right Source**: Microsprinkler-applied PN always outperformed PTS and SOP under comparable conditions or when compared with current practice, although yield increases were not always statistically different. Greatest yield was found at 60% of required K as banded SOP and 40% of required K as continuous fertigated PN.

2. **Right Rate**: In these experiments application of 224 kg K/ha resulted in the highest yields; no benefit from applications of K at greater rates.

3. **Right Time**: Continuous fertigation (22 events) gave greater yield than pulse fert (4 events). Proportion of nutrients applied according to demand:
   - Feb-Mar: 20%
   - Apr-May: 30%
   - Jun-mid-Jul: 30%
   - early PH (Sept): 20%

4. **Right Place**:
   a) Yield of Fan jet irrigated trees was modestly higher compared to drip irrigated trees under almost all treatments and fertiliser sources.
   b) Nitrogen use efficiency (per hectare) of Fan jet irrigated trees increased from 73% with pulse to 93% with continuous fertigation.
Fertilizer recommendation for fertigated California almonds for superior yield and greatest total nitrogen recovery

• Fertilization programme

<table>
<thead>
<tr>
<th>Moment</th>
<th>Application</th>
<th>Source</th>
<th>Dose</th>
<th>N</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kg/ha</td>
<td>Kg/ha</td>
<td>Kg/ha</td>
</tr>
<tr>
<td>February</td>
<td>Basal</td>
<td>SOP</td>
<td>336</td>
<td></td>
<td>140</td>
</tr>
<tr>
<td>March - early post-harvest</td>
<td>Microsprinkler - fertigated</td>
<td>UAN</td>
<td>1020</td>
<td>306</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PN</td>
<td>220</td>
<td>30</td>
<td>84</td>
</tr>
</tbody>
</table>

• Continuous Fan jet microsprinkler fertigation
  – Fertilizers to be applied in as many split applications as possible to retain nitrogen in the shallow root zones in order to prevent leaching
  – Proportion of nutrients applied according to demand:
    Feb-Mar: 20%. Apr-May: 30%. Jun-mid-Jul: 30%. early PH (Sept): 20%
  – The injection of the fertilizer in a fertigation event be concentrated toward the end of the irrigation event (last few hours).
PNA website
www.KNO3.org
PNA Website - scientific library
155 abstracts in English, Spanish, Chinese
Topics of this edition:

- How the combination of foliar applied potassium nitrate and paclobutrazol increased fruit retention and average fruit weight in avocado.
  
  read more (English)
  read more (Spanish)
  read more (Chinese)

- Potassium nitrate outperformed potassium chloride and potassium sulphate as the K source in making up fertigation solutions for crops growing in desert soils under highly saline conditions.
  
  read more (English)
  read more (Spanish)
  read more (Chinese)
Dear reader,

We are pleased to present you the third edition of the PNA Newsletter!

This newsletter covers three topics: the newly created scientific potassium nitrate library, now available on the PNA website, and the benefits of foliar-applied potassium nitrate on crops. The outcomes of two PNA funded research projects in Vietnam and the USA about the positive effects of foliar applied potassium nitrate on rice yield increase and reduced lodging incidence will be presented.
PNA website – (m.kno3.org)
Easy reading on mobile device
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