Calcium Nutrition in
• Apple Trees
and Vegetable crops

Barry Bull,
Hydro Agri
Specialities,
September 2003
Calcium in the plant!

What does calcium do?
Calcium promotes root and shoot growth!

Tomatoes

Strawberries
Calcium – promotes fruit quality

+ Ca

- Ca
Calcium – promotes fruit quality

+ Ca

- Ca
Calcium – promotes fruit quality

+ Ca

- Ca
Calcium – promotes fruit quality

+ Ca

- Ca
Calcium – promotes fruit firmness

+ Ca

- Ca
Calcium – reduces splitting

+ Ca

- Ca
Calcium in the plant!

Where does calcium go?
<table>
<thead>
<tr>
<th>N source</th>
<th>1990 soil pH 15 (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Nitrate</td>
<td>6.39 a</td>
</tr>
<tr>
<td>16:16:16</td>
<td>5.02 b</td>
</tr>
<tr>
<td>Ammonium Nitrate</td>
<td>4.69 c</td>
</tr>
<tr>
<td>MAP</td>
<td>4.58 c</td>
</tr>
</tbody>
</table>

Differences at 5% level

Source: Raese, J.T. 1994

Fertilizer applied 1985-1989 to Apples
Calcium Nitrate is a fast dissolving fertilizer
(incubated for 4 hours at 25 °C and 60 % rel. humidity)

Calcium nitrate
(uncoated granule, field grade)

Calcium carbonate
(powder, p.a. quality)

1.3 cm

1 hour

3.1 cm

4 hours

Fertilizer

Ca migration
changes colour of filter paper
to dark blue

Filter paper treated with light blue Ca indicator
Calcium in Valencia Oranges - Florida

- Long-term trial (results after 7 to 8 years)
- Soil pH 6.0 - after liming with soda ash or lime (CaCO₃)

Yield (box/acre)

- Soda ash (no Ca)
- Lime
- Lime + soluble Ca (+ Ca: 100 lbs/acre)
- Lime + soluble Ca (+ Ca: 300 lbs/acre)

Source: Anderson (1971 - USA)
# Apples

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Weight (Kg/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>860</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.57</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.59</td>
</tr>
<tr>
<td>Potassium</td>
<td>2.05</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.04</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.05</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Why Calcium is important in Apple trees !!
Calcium improves:

- storage qualities
- skin presentation
- tolerance to physical stress
- tolerance to disease invasion
- fruit retention
Calcium at flowering reduces fruit drop

In citrus and other fruits
Stem Retention

<table>
<thead>
<tr>
<th>Stem</th>
<th>N</th>
<th>Ca</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>with</td>
<td>1.36</td>
<td>0.22</td>
<td>Same</td>
</tr>
<tr>
<td>without</td>
<td>0.94</td>
<td>0.14</td>
<td>Same</td>
</tr>
</tbody>
</table>

Cherries - California, June 2000
- Analysis of cherry tops from stemmed and stemless cherries.
- Indicates calcium related to abscission of stems.
Calcium moves mainly in the transpiration stream

Adapted from an original diagram supplied courtesy of SQM
Calcium moves mainly to older leaves

Calcium is not redistributed from older to younger leaves or from leaves to fruits or seeds.

Calcium uptake follows the water uptake and distribution in the plant.
Calcium related disorders especially in storage

✓ Caused by:
  ➨ poor calcium nutrition
  ➨ poor distribution of calcium
  ➨ excess potassium
  ➨ excess nitrogen
  ➨ insufficient calcium applications
Bitter Pit

Small dark corky area below skin

Cause:
localised calcium deficiency
Bitter Pit

Apple - bitter pit symptoms in Bonza variety of apple.

Cause:
localised calcium deficiency
Bitter Pit

Small dark corky areas below skin

Cause:
localised calcium deficiency

Apple - a section through the fruit showing indented skin and brown corky tissue in the flesh beneath the skin.
Bitter Pit

Most susceptible apples are:

- Fruit on vigourous, leafy, upright branches
- Young trees just coming into bearing
- Fruit on heavily pruned trees
- Fruit harvested when immature
- Biennial bearing trees
- Varieties vary in susceptibility
Watercore Breakdown

- Waxy look about flesh
- Glassy appearance
- Soft fruit

Cause:
- High K : Ca
- High Mg : Ca
- Low phosphorus
Calcium & Fire Blight

- Erwinia amylovora
- Increasing Ca in blossom reduces fire blight
- Applying calcium nitrate doubled the Ca content of blossom from 0.25% to 0.49% compared to ammonium nitrate
Root disease

Nitrogen source affects susceptibility to root disease

Adding calcium makes a difference
Observation from Florida

Calcium improves root tolerance to weevil attack
Calcium Nitrate increases

- cold tolerance of apples
- red colour in ‘Red Delicious’
- yield and vigour compared to ammonium nitrate
- white flesh colour in ‘Golden Delicious’
- calcium content of fruit while lowering N, P, K & Mg
Soil-Applied Fertilizer Effects on ‘Red Delicious' Apples

<table>
<thead>
<tr>
<th>Fertilizer treatments</th>
<th>Yield/tree kg</th>
<th>Bitter pit %</th>
<th>Red area %</th>
<th>Fruit cortex Ca (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium Nitrate</td>
<td>36.1</td>
<td>1.5 c</td>
<td>61 ab</td>
<td>194</td>
</tr>
<tr>
<td>Calcium Nitrate</td>
<td>38.0</td>
<td>1.8 bc</td>
<td>73 a</td>
<td>215</td>
</tr>
<tr>
<td>MAP</td>
<td>36.1</td>
<td>7.6 a</td>
<td>50 b</td>
<td>202</td>
</tr>
<tr>
<td>16-16-16</td>
<td>32.3</td>
<td>5.1 ab</td>
<td>53 b</td>
<td>191</td>
</tr>
</tbody>
</table>

Differences at 5% level

Soil-Applied Fertilizer Effects on 'Golden Delicious' Apples

<table>
<thead>
<tr>
<th>Fertilizer treatments 1985-87</th>
<th>Yield/tree kg</th>
<th>Bitter pit %</th>
<th>Fruit finish 1-8</th>
<th>Fruit peel Ca (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium Nitrate</td>
<td>24  b</td>
<td>2.5 ab</td>
<td>5.2 ab</td>
<td>383</td>
</tr>
<tr>
<td>Calcium Nitrate</td>
<td>34ab</td>
<td>0.7 b</td>
<td>6.0 a</td>
<td>444</td>
</tr>
<tr>
<td>MAP</td>
<td>34ab</td>
<td>5.0 a</td>
<td>4.5 b</td>
<td>403</td>
</tr>
<tr>
<td>16-16-16</td>
<td>41 a</td>
<td>3.3 ab</td>
<td>5.1 b</td>
<td>425</td>
</tr>
</tbody>
</table>

Differences at 5% level
Fruit finish: 8=excellent, 1=poor

When to apply calcium

- 90% of the calcium in apples is taken up in the first 4 to 6 weeks after bloom.
- Calcium sprays ensure calcium levels build in the fruit.
Calcium uptake in apples

- Period of main calcium uptake in the fruit
- Period of calcium dilution dependent on fruit growth
- Calcium is sufficient in small apples
- The fruit has nearly received all its calcium
- The calcium content per fruit within the tree is the same regardless of size
- Calcium is diluted in large apples so that it is inadequate to prevent disorders

- Bloom and fruit set
- Harvest
Correcting Calcium disorders

- Increase number of applications
- Avoid excessive pruning
- Have a balanced nutrition program
- Selectively harvest fruit as it ripens
Quality – market acceptance

- Apple grower applies calcium nitrate to soil after flowering and regularly sprays Calcium nitrate on green apples. (up to 18 sprays)

- Result: - Buyers in market are always looking for his fruit, regardless of the market supply. No bitter pit gives the buyers confidence.

**Benefit:** Calcium nitrate reduces Bitter Pit in apples
Calcium and heat stress in Potatoes
Potato is a cool season crop

Hot dry weather is not beneficial

Low levels of calcium in the leaf make the plant susceptible to foliar damage from heat stress.

Calcium is important for the active transport of K for the regulation of stomatal openings.

Low calcium levels in leaf means poor control of the stomata even with high K levels.
Calcium & heat stress

- Biotron studies from Wisconsin University show that:
  - Plants with Ca produced 1.0 kg of tubers / plant
  - Plants without calcium were heat stressed and produced 0.7 kg of tubers / plant
- A yield reduction of 30%
Calcium & crop stress

The full study showed nitrogen during the stress helped but Ca & N was better.

<table>
<thead>
<tr>
<th>Fert applied</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>N only before stress</td>
<td>100 %</td>
</tr>
<tr>
<td>N only during stress</td>
<td>117 %</td>
</tr>
<tr>
<td>Ca &amp; N during stress</td>
<td>167 %</td>
</tr>
</tbody>
</table>

Calcium nitrate relieves heat stress in potatoes
Calcium and Potato Disease
**Calcium & Erwinia**

- Ca improves tolerance to disease

<table>
<thead>
<tr>
<th>Peel Ca</th>
<th>Surface area decayed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 %</td>
<td>90 %</td>
</tr>
<tr>
<td>0.2%</td>
<td>50 %</td>
</tr>
<tr>
<td>0.3%</td>
<td>20 %</td>
</tr>
<tr>
<td>0.5 %</td>
<td>nil</td>
</tr>
</tbody>
</table>

![Image of apple sections with decayed areas]
Calcium & Erwinia

- Increasing calcium in cortex (red) & periderm (blue)
- Deceases soft rot (yellow)

% Wt. Loss From Soft Rot

Cortex (x 10^-1)
Periderm

University of WI

*Bacterial
Calcium & Internal Rust Spot

◆ Ca improves tolerance to disease

<table>
<thead>
<tr>
<th>Ca</th>
<th>IRS</th>
<th>Peel Ca</th>
</tr>
</thead>
<tbody>
<tr>
<td>nil</td>
<td>60 %</td>
<td>0,11 %</td>
</tr>
<tr>
<td>84</td>
<td>37 %</td>
<td>0,13 %</td>
</tr>
<tr>
<td>252</td>
<td>17 %</td>
<td>0,15 %</td>
</tr>
</tbody>
</table>
Calcium & Internal Brown Spot (IBS)

- Ca in the inner part of tubers:
  Slight variations can make the difference

% of IBS

Ca in tuber flesh (% of DM)

- Tuber flesh, Site 1
- Tuber flesh, site 2
Ca in tubers & Internal Brown Spot (IBS)

\[ R^2 = 0.5701 \]

\[ R^2 = 0.1851 \]

- **Pulp**: Tuber flesh, Site 1, Tuber flesh, site 2, Linear (Tuber flesh)
- **Skin**: Tuber skin, Site 1, Tuber skin, site 2, Linear (Tuber skin)
Calcium and Potato Skin Finish
**Calcium – Skin finish**

**FIGURE 19**

**CALCIUM AND SKIN FINISH**

- **Disorder index (severity x incidence)**
  - AN control
  - CN liquid
  - CN solid

- Skin finish
- Common scab
- Powdery scab
- Black scurf
- Silver scurf / 10

REF: HYDRO FUNDED INDEPENDENT TRIALS - 1998
Ca & tuber storage

Ca in the outer skin

Confers resistance against pressure

Calcium (% DM)

Resistance against pressure (g)

1 year trial, 2001
Germany

Cooperation
Hydro Agri / Uni. Goettingen / Bahlsen
Ca & tuber bruising

- All varieties increased in calcium
- All varieties had less bruising

- Ca @ 165 kg/ha
- Combination of CN & CaCl

Karlsson & Palta
Uni. Of Wisconsin
2001
Does it work?

- **Example**: In Australia - average peel analysis.
  - Ca ranged from 0.07 to 0.11%
  - Desired level at least 0.15%

- **CN rates used**
  - 125 kg/ha solid when tubers 25mm
  - 25 kg/ha/week fertigated for 6 weeks
  - Total 275 kg/ha CN

- Farmer increased his Ca levels to 0.15%
- Skin blemishes decreased from 16% to 8%

- **Cost / Benefit**
  - Cost Aus $192.5/ha
  - Benefit Aus $1088/ha
Calcium and Potato Yield
The importance of calcium in potato nutrition is demonstrated in an experiment where seed potatoes were grown with and without calcium.

Crops grown with these seed pieces showed substantial differences.
Calcium nitrate improves subsequent yield of seed potatoes:

<table>
<thead>
<tr>
<th></th>
<th>+ Calcium</th>
<th>- Calcium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic</td>
<td>73</td>
<td>47</td>
</tr>
<tr>
<td>Norland</td>
<td>62</td>
<td>54</td>
</tr>
<tr>
<td>Superior</td>
<td>70</td>
<td>71</td>
</tr>
</tbody>
</table>

+ Ca = Calcium nitrate
- Ca = Ammonium nitrate
Minituber production using hydroponics

Calcium nitrate removed
Tuber skins cracked and peeled
Internal breakdown.
Calcium uptake in tubers
Most Calcium absorption occurs from tuber initiation and throughout tuber bulking.
Calcium uptake is through stolon and tubers.

<table>
<thead>
<tr>
<th>Ca applied ppm</th>
<th>Ca % DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stolon/tuber</td>
<td>Main root</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>100</td>
<td>3000</td>
</tr>
<tr>
<td>3000</td>
<td>100</td>
</tr>
<tr>
<td>Field grown</td>
<td></td>
</tr>
</tbody>
</table>
Main Roots

- (dyed water travels up to stem not into stolons and tuber)
Stolon - tuber connection

Stolons pick up dyed water

dyed water travels into tuber
Moving Ca into potatoes

- Foliar Ca remains in the leaf
- Stolon and tuber roots take in Ca for the tubers
- Soil Ca moves upwards into the leaves
Applying CN

Dry apply and incorporate

Through watering system

Both ways are effective in moving Ca over the tubers

Apply in time for rapid cell division.
Calcium Analysis
Tissue analysis:

- Calcium levels in the leaf at start of flowering should be between 1 & 2 %
- If below these levels – yield will be lower.
- Leaf analysis is not a good indicator of tuber Ca levels.
Tuber analysis:

Tubers need higher levels of Calcium.
- Calcium levels are 3 to 5 times higher in peel than whole tuber.
- 0.15% Ca in peel will give better skin finish
- 0.2% Ca in peel gives good disease tolerance
Calcium in potatoes improves:

- Tolerance to heat and cold stress
- Tolerance to diseases
  - Less internal tuber breakdown
  - Better skin finish
- Yield:
  - where soil Ca levels low
  - where heat or cold stress results from low Ca levels

Calcium is vital to potatoes