Nitrogen, Potassium and Calcium in Potatoes

Barry Bull,
Hydro Agri Specialities
September 2003
<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Tuber Size</th>
<th>Tuber Number</th>
<th>Tuber Quality</th>
<th>Skin Finish</th>
<th>Storage Quality</th>
</tr>
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<tbody>
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<td>Ca</td>
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<td>Mg</td>
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<td>B</td>
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<td>Zn</td>
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Role of nutrients in Potatoes
Nitrogen
Nitrogen

- For yield
  - more nitrogen
  - higher yields
  - lower bulk density
Nitrogen

- For quality
  - high nitrogen
    - split potatoes
    - poor cooking quality
    - brown stains in crisps
    - slow skin-set
Sidedressing nitrogen

- Split applications with one sidedress
  - 2/3 N applied at seeding
  - 1/3 N applied around tuber initiation

Apply N when ‘hilling up’

- More applications are better
## Splitting Nitrogen Applications

<table>
<thead>
<tr>
<th>Total N</th>
<th>Appl. Split</th>
<th>t/ha</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>39.6</td>
</tr>
<tr>
<td>60</td>
<td>60</td>
<td>47.9</td>
</tr>
<tr>
<td></td>
<td>30+30</td>
<td>52.2</td>
</tr>
<tr>
<td>90</td>
<td>90</td>
<td>55.3</td>
</tr>
<tr>
<td></td>
<td>60+30</td>
<td>58.6</td>
</tr>
<tr>
<td></td>
<td>30+30+30</td>
<td>61.8</td>
</tr>
<tr>
<td>120</td>
<td>120</td>
<td>56.3</td>
</tr>
<tr>
<td></td>
<td>90+30</td>
<td>61.7</td>
</tr>
<tr>
<td></td>
<td>60+30+30</td>
<td>61.9</td>
</tr>
<tr>
<td>150</td>
<td>150</td>
<td>61.1</td>
</tr>
<tr>
<td></td>
<td>120+30</td>
<td>59.0</td>
</tr>
<tr>
<td></td>
<td>90+30+30</td>
<td>66.1</td>
</tr>
</tbody>
</table>
Effect of Nitrogen form & rate:

Tuber yield in South Africa (cv. UTD)

Ref: O. Achilea et al., 2000
Nitrogen - source

- Ammonium nitrogen
  - Excess NH$_4^+$ is toxic and reduces yield
  - NH$_4^+$ Cannot be stored
  - NH$_4^+$ must be detoxified

- Nitrate nitrogen
  - not toxic
  - efficient
  - potatoes prefer nitrate
CN vs. AN
Potassium
Potassium

- Increases tuber number
- Decreases tuber bruising
- Decreases enzymatic discolouration during cooking
- Anti Stress Element
Field trials - results Bulgaria 1996

MT/ha

KNO3  K2SO4  KCl

22  23  24  25  26  27  28  29
Effect of K on % damaged tubers

Source: Hunnius und Bachthaler - IPI
Mc Cains - Trial UK ‘97

Trial: Basedresser based on KCl just before planting
Topdressing: with KNO3 217 kg/ha <-> AN

Number of tubers bruised (SAC damage barrell)

<table>
<thead>
<tr>
<th></th>
<th>No KNO3</th>
<th>+KNO3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of tubers bruised</td>
<td>170</td>
<td>130</td>
</tr>
</tbody>
</table>

- Trial details: Basedresser-based application of KCl just before planting, followed by topdressing with KNO3 at 217 kg/ha.
- The graph shows the number of tubers bruised with and without KNO3 application, indicating a reduction in bruising with KNO3.
Trial Mc Cains ‘97 - UK

Number of peels, necessary to completely remove the bruise

Number of Peels

<table>
<thead>
<tr>
<th>No KNO3</th>
<th>+KNO3</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td>800</td>
</tr>
<tr>
<td>1000</td>
<td>900</td>
</tr>
<tr>
<td>1100</td>
<td>1000</td>
</tr>
</tbody>
</table>
Potassium and Tuber Quality

- Effect of Potassium on discoloration

Mondy & Munshi 1993
Potassium as Anti stress element: stomata regulation

Source: Blanchet et Al., 1962
**K effect on Low Temperature Tolerance**

<table>
<thead>
<tr>
<th>K applied (lb/A)</th>
<th>Yield (tons/A)</th>
<th>Foliage Damaged by Frost (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5.9</td>
<td>30</td>
</tr>
<tr>
<td>50</td>
<td>6.7</td>
<td>16</td>
</tr>
<tr>
<td>100</td>
<td>7.1</td>
<td>7</td>
</tr>
</tbody>
</table>

Calcium and heat stress
- 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>
Calcium & Erwinia

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

**Graph:**
- **X-axis:** % Ca
- **Y-axis:** % Wt. Loss From Soft Rot
- **Legend:**
  - **Cortex (x 10^-1)**
  - **Periderm**
  - **Soft Rot**

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

![](image)

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**Calcium (Ca) in Tuber Flesh (% of DM)**

- Tuber flesh, Site 1
- Tuber flesh, site 2

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Ca in tubers & Internal Brown Spot (IBS)

![Graph showing the relationship between Ca (% of DM) and % of IBS for tuber flesh and tuber skin with R² values of 0.5701 and 0.1851 respectively.](image)

- **Tuber flesh, Site 1**
- **Tuber flesh, site 2**
- **Tuber flesh**
- **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**

<table>
<thead>
<tr>
<th>Disorder index (severity x incidence)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>AN control</td>
</tr>
</tbody>
</table>

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

REF: HYDRO FUNDED INDEPENDENT TRIALS - 1998
Calcium and skin finish

- Tubers need at least 0.15% Ca in peel
- 0.2% is better for disease tolerance.
Ca & tuber storage

- Ca in the outer skin

Confers resistance against pressure

Graph:

- 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

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**Incidence of Bruising (%)**

- Tuber Calcium levels (ppm)

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**Amm Nit**

- CN.CaCl

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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
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>

Field grown
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

Stolon and tuber roots take in Ca for the tubers

Foliar Ca remains in the leaf

Soil Ca moves upwards into the leaves
Tuber initiation

Varies with variety - digging is the best way to see
Applying CN

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
<table>
<thead>
<tr>
<th></th>
<th>Tuber Size</th>
<th>Tuber Number</th>
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<th>Skin Finish</th>
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<tbody>
<tr>
<td><strong>N</strong></td>
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<td>+</td>
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<tr>
<td><strong>P</strong></td>
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<tr>
<td><strong>K</strong></td>
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<tr>
<td><strong>Ca</strong></td>
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<td><strong>Zn</strong></td>
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<td></td>
<td>+</td>
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</tbody>
</table>

Role of nutrients in Potatoes

- **N** - Nitrogen
- **P** - Phosphorus
- **K** - Potassium
- **Ca** - Calcium
- **Mg** - Magnesium
- **S** - Sulfur
- **Mn** - Manganese
- **B** - Boron
- **Zn** - Zinc
Is it worth the effort?

- Australian example – sandy soil
- Increased in program
  - Nitrates
  - Calcium
  - Magnesium
- Yield: no difference
- Quality - Packout
  - major improvement

- Cost: extra $A 290.00
- Return: extra $A 3995.45

Nutrition is vital to potatoes