Calcium: Its role in crop production

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Classic calcium deficiency -

Blossom-end rot in tomato caused by Ca deficiency

Bitter pit/cork spot in apples
Soybean

Corn

Canola

Wither-tip, Tipple-top
Calcium in plants

- Enters through roots in the transpiration stream.
- Moves up the plant to the ends where water evaps.
- Not remobilized.
- Poor supply to low transpiring tissues
- Ends up mainly as calcium pectate in cell walls.

*Symptoms of deficiency:*
*Breakdown in newly formed cell walls.*
Calcium demand by different species:

- Top lines are canola, bottom line is wheat.
- Critical values for $Y_{\text{max}}$.
  - Wheat – 150 mg/pot
  - Canola - ~400 mg/pot
- Nutrient densities & removal
  - Wheat – 400 mg/kg (0.4 kg/t)
  - Canola – 4000 mg/kg (4 kg/t)
  - Pulses – 1000 mg/kg (1 kg/t)

## Values for critical tissue Ca levels

<table>
<thead>
<tr>
<th>Crop</th>
<th>Stage</th>
<th>Part</th>
<th>Adequate</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canola</td>
<td>Pre-flow</td>
<td>YML</td>
<td>1.4-3.0%</td>
<td>Weir, 1983</td>
</tr>
<tr>
<td></td>
<td>Pre-flow</td>
<td>1,2,3 RML</td>
<td>1.4-3.0</td>
<td>Weir, unpub.</td>
</tr>
<tr>
<td>Wheat</td>
<td>2-3 leaf</td>
<td>YEB</td>
<td>0.3-0.8%</td>
<td>Peverill, unpub.</td>
</tr>
<tr>
<td></td>
<td>Mid-late Till</td>
<td>YMB</td>
<td>0.2-0.4%</td>
<td>Weir, 1983</td>
</tr>
<tr>
<td>Field pea</td>
<td>Pre-fl</td>
<td>YML</td>
<td>0.9-2.0%</td>
<td>Weir &amp; Cresswell, 1994</td>
</tr>
</tbody>
</table>

Source, Reuter & Robinson, Plant Analysis.
A transport problem?

- Ca moves in the xylem so goes to the actively transpiring tissues (i.e., leaves).
- Ca is nearly all supplied in this new stream.
- Tissues with low transpiration rates (e.g., fruits) will lack Ca.
- Uneven water supply can result in poor Ca transport.

- So – in most cases it is a transport problem!

*Take care with tissue sampling*
pH and nutrient availability

• Soil acidity (pH) drives much of the chemistry in the soil
• Reactions to free or to bind nutrients driven by soil pH
• At pH < 5.5 subscripts W calcium becomes less available.
  – Cation substitution & losses
• At pH > 8.5 subscripts W calcium becomes less available
  – Insoluble calcium carbonates
  – Solubility of \( \text{CaCO}_3 \) is decreased at higher soil pH.

Note pH subscripts W is 0.7 to 1.0 greater than pH subscripts \( \text{CaCl}_2 \).
Clay colloids 101:

- Clays are negatively charged
- Electrostatically attract cations
- Strength depends on the charge and size of the cations (hydrated diameter – Table 1 incorrect)
- A small ion (e.g., 300 pm K\(^+\)) is held more strongly than a large ion (e.g., 450 pm Na\(^+\)).
- Charge number is also important.

Na 450, K 300, Mg 800, Ca 600, Al 900.
$\text{Al}^{3+} > \text{H}^+ > \text{Ca}^{2+} > \text{Mg}^{2+} > \text{K}^+ = \text{NH}_4^+ > \text{Na}^+$
$Al^{3+} > H^{+} > Ca^{2+} > Mg^{2+} > K^{+} = NH_{4}^{+} > Na^{+}$
Soil Ca levels:

- Usually expressed as ammonium acetate exchangeable calcium in cmol/kg of soil.
- 1 cmol/kg top 10 cm equates to ~400 kg of ex-Ca.
  - ie it is in an ionic and plant available form!
- 2-5 cmol/kg (about 0.5 mmol/l)
# Exchangable cations and interpretations (cmol/kg)

<table>
<thead>
<tr>
<th></th>
<th>Sodium</th>
<th>Potassium</th>
<th>Calcium</th>
<th>Magnesium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low</td>
<td>&lt;0.1</td>
<td>&lt;0.2</td>
<td>&lt;2</td>
<td>&lt;0.3</td>
</tr>
<tr>
<td>Low</td>
<td>0.1-0.3</td>
<td>0.2-0.3</td>
<td>2-5</td>
<td>0.3-1.0</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.3-0.7</td>
<td>0.3-0.7</td>
<td>5-10</td>
<td>1-3</td>
</tr>
<tr>
<td>High</td>
<td>0.7-2.0</td>
<td>0.7-2.0</td>
<td>10-20</td>
<td>3-8</td>
</tr>
<tr>
<td>Very High</td>
<td>&gt;2</td>
<td>&gt;2</td>
<td>&gt;20</td>
<td>&gt;8</td>
</tr>
</tbody>
</table>


Very much a guide only.
Base saturation cation ratios

- Have been around for 60 years, proposed that there is an optimal “balance” between Ca, Mg, Na, K (the base cations).
Effect of Ca:Mg ratio on cotton

Our examination of the data from numerous studies (particularly those of Albrecht and Bear themselves) would suggest that, within ranges commonly found in soils, the chemical, physical and biological fertility of a soil is not influenced by the ratios of Ca, Mg, and K. The data do not support the claims of BCSR and continued promotion of the BCSR will result in the inefficient use of resources in agriculture and horticulture.

Kopittke & Menzies, 2007, SSSAJ, 71:259
Question 7
So why do laboratories still quote BCSR and Ca:Mg ratios?

A. **I have no idea.**

• Dr D Edmeades, New Zealand
  - [http://www.agknowledge.co.nz](http://www.agknowledge.co.nz)
  - Soil Ca, expressed as the % Ca base saturation is meaningless and misleading – Ignore it.

• What is important is the actual level of the calcium and magnesium – both should be above 0.5 mmol/l in the soil solution - 2-3 cmol/kg.
Lime – calcium carbonate

- It is not a fertilizer, it is a soil ameliorant.
- The calcium plays NO ROLE in amending the soil pH – it is a spectator ion.
- The carbonate/bicarbonate reacts with hydrogen ions as:
  \[ \text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2 \] (quite quick)
- Lime has a low solubility – 0.013 g/l (pH & temp.)
  - its solubility declines significantly with pH – above pH 9, the solubility will be about 1/20th of it at pH 7.
  - Lime usually requires incorporation to react with the soil volume.
- It takes time for lime to dissolve and dissociate to Ca.
  - Depending on soil pH – it may not dissolve or dissociate
  - At high pH, it can ‘trap” ex-Ca.
On an acid soil...adding lime

\[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{CO}_3^{2-} \]
Gypsum – Calcium sulfate dihydrate

• It is not a fertilizer but a soil ameliorant
• The sulfate ion plays no role in the soil reactions, but it can supply S to demanding crops (e.g., canola).
• Calcium displaced sodium off the clay, assisting with flocculation of the clay particles.
• Gypsum has a solubility of 2.4 g/l but will still need 100 mm of rain to dissolve a tonne get into the soil
  – (burning stubbles?).
• In soils with free carbonate, calcium may be precipitated into lime.
On an alkaline soil ........ adding gypsum

Sodic clay to a calcic clay

Clay Particle

SO$_4^{2-}$

CO$_3^{2-}$

LIME
Gypsum & Lime  (Rengasamy, pers.comm.)

• Up until pH 8.5, Ca is derived from the dissolution AND dissociation of lime or gypsum.

• These are equilibrium reactions based on the $K_s$:
  - $\text{CaCO}_3 \leftrightarrow \text{Ca}^{2+} + \text{CO}_3^{2-}$ (100 mm)
  - 1 tonne of lime (40% Ca) $\rightarrow$ g’s of $\text{Ca}^{2+}$ + carbonate (replenished)
  - $\text{CaSO}_4 \leftrightarrow \text{Ca}^{2+} + \text{SO}_4^{2-}$ (100 mm)
  - 1 t of gypsum (15% Ca) – kg’s of Ca (all dissolved)

• Supply is not about solubility alone – it is rate * solubility in an equilibrium reaction.
  - A low rate of a “highly soluble” product may not supply as much as a high rate if a “poorly soluble” product.
  - High rate of low soluble means a back up supply over time.
Do you have any now?

• Soil test? 1 cmol/kg = 400 kg/ha Ca

• Using gypsum on sodic soils?
  – Good quality gypsum has >15% Ca

• Do you use/recommend lime –
  – Raise soil $pH_w$ above 5.5, will provide adequate Ca.

• Do you use SSP or TSP?
  – 100 kg/ha SSP (20% Ca) = 20 kg/ha Calcium
  – 40 kg/ha TSP (15% Ca) = 6 kg/ha Calcium
  – DAP/MAP = nil
Using fluid calcium sources?

As a nutrient source (eg Ca Nitrate/ Ca Ammonium nitrate):

- Clearly done in horticulture as foliar sprays – high value crops for storage disorders.
- Most often the problem in canola is transport, low transpiration rate and/or dry soil.
- Trials?

Kandle & Porter, Minnesota

<table>
<thead>
<tr>
<th>Crop</th>
<th>Without Calcium</th>
<th>With Calcium</th>
<th>L.S.D. 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield (lb/a)</td>
<td>2736</td>
<td>2561</td>
<td>N.S.</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>22.8</td>
<td>23.4</td>
<td>N.S.</td>
</tr>
<tr>
<td>Relative Forage Quality</td>
<td>173</td>
<td>189</td>
<td>N.S.</td>
</tr>
<tr>
<td>Milk per Ton (lb/ton)</td>
<td>2521</td>
<td>2704</td>
<td>N.S.</td>
</tr>
<tr>
<td>Oats</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield (bu/a)</td>
<td>122</td>
<td>119</td>
<td>N.S.</td>
</tr>
<tr>
<td>Test weight (lb/bu)</td>
<td>36.8</td>
<td>37.1</td>
<td>N.S.</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield (bu/a)</td>
<td>32.3</td>
<td>30.8</td>
<td>N.S.</td>
</tr>
<tr>
<td>Test weight (lb/bu)</td>
<td>61.8</td>
<td>61.5</td>
<td>N.S.</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>13.1</td>
<td>13.0</td>
<td>N.S.</td>
</tr>
<tr>
<td>Soybean¹</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield (bu/a)</td>
<td>7.3</td>
<td>6.4</td>
<td>N.S.</td>
</tr>
<tr>
<td>Height (inch)</td>
<td>17.4</td>
<td>16.3</td>
<td>N.S.</td>
</tr>
<tr>
<td>All Crops Combined</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yields expressed as % of non treated crop</td>
<td>100</td>
<td>98.3</td>
<td>N.S.</td>
</tr>
</tbody>
</table>
Using fluid calcium sources?

As a structural amendment:
Calcium to displace sodium off the colloid.
Solubility is not the issue – it is the amount of Ca supplied.

To halve ESP from 7% - 400 kg/ha of Ca (1 cmol/kg)
• 1 t/ha of gypsum will supply ~100 kg/ha of Ca ions with 100 mm of rain.
• A 5% calcium nitrate solution would need to be applied at 2000l/ha to achieve the same supply of Ca ions.
  – Maybe there is a “localized” effect where applied – but this strip would be under “chemical siege” from the surrounding Na.
Summary

Where will added Calcium be a benefit

• Where pH <5 – why not add lime anyway

• Where pH>9 – grow a legume/use elemental S
  – Is a degree of uncertainty about this area.

• When growing sensitive crops (almonds, peanuts, apples) on acid soils.
  – Canola and added Ca? No reliable replicated data on this.
  – Adding to N efficiency. No reliable replicated data on this.