What’s new in zinc?

plus some critical reminders

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Better Crops, Better Environment ... through Science

Temora, February 11, 2014.
Response to Zn

Yield Response to 7.5 kg Zn – 2 of 6 sites

Grain Zn Increase on 5 of 6 sites

Highly site specific, responses depend on site selection, & test crop & product used

Peck et al 2008
Is zinc a big problem?

• Globally – yes
  – Most widespread soil micronutrient deficiency
  – 450,000 children die each year due to Zn deficiency
  – Focus of global research to enhance grain Zn (&Fe) – bio-fortification.

• In Australia – yes
  – Is the major micronutrient deficiency for us.
  – Early reports of chronic deficiency, now uncommon.
  – 8 Mha in WA, 70-80% of SA, Vertosols,
  – Change to AP’s, tight rotations, reduced tillage, liming, ALS-herbs.

• For you and your clients?
# Occurrence of low soil test and grain Zn levels

<table>
<thead>
<tr>
<th>ASC Order</th>
<th>pH (CaCl$_2$) (0-10 cm)</th>
<th>Clay % (L1)</th>
<th>OC%</th>
<th>Mean Critical Zn (mg kg$^{-1}$)</th>
<th>DTPA Zn (0-10 cm) (mg kg$^{-1}$)</th>
<th>Wheat Grain Zn (mg kg$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcarosol</td>
<td>7.3±0.1</td>
<td>18±9</td>
<td>1.7±1.6</td>
<td>0.25</td>
<td>1.1±0.7</td>
<td>18.6±0.9</td>
</tr>
<tr>
<td>Chromosol</td>
<td>5.6±0.1</td>
<td>14±7</td>
<td>2.1±1.3</td>
<td>0.20</td>
<td>2.1±0.3</td>
<td>22.6±1.1</td>
</tr>
<tr>
<td><strong>Dermosol</strong></td>
<td><strong>6.8±0.1</strong></td>
<td><strong>29±9</strong></td>
<td><strong>2.5±1.5</strong></td>
<td><strong>0.26</strong></td>
<td><strong>0.8±0.6</strong></td>
<td><strong>16.7±3.0</strong></td>
</tr>
<tr>
<td>Ferrosol</td>
<td>6.6±0.2</td>
<td>15±8</td>
<td>*</td>
<td>1.7±0.9</td>
<td>1.4±0.4</td>
<td>17.3±0.9</td>
</tr>
<tr>
<td>Kandosol</td>
<td>5.3±0.1</td>
<td>12±4</td>
<td>1.8±1.0</td>
<td>0.21</td>
<td>1.4±0.4</td>
<td>17.3±0.9</td>
</tr>
<tr>
<td>Sodosol</td>
<td>6.7±0.1</td>
<td>14±7</td>
<td>2.9±1.4</td>
<td>0.21</td>
<td>0.8±0.4</td>
<td>17.8±0.5</td>
</tr>
<tr>
<td>Tenosol</td>
<td>6.0±0.2</td>
<td>11±6</td>
<td>2.0±0.8</td>
<td>0.19</td>
<td>0.6±0.9</td>
<td>21.7±1.3</td>
</tr>
<tr>
<td>Vertosol (pH&lt;7.0)</td>
<td>6.3±0.1</td>
<td>44±4</td>
<td>1.7±1.1</td>
<td>0.32</td>
<td>0.8±0.4</td>
<td>23.6±0.8</td>
</tr>
<tr>
<td><strong>Vertosol (pH&gt;7)</strong></td>
<td><strong>7.8±0.1</strong></td>
<td><strong>44±4</strong></td>
<td><strong>1.4±0.6</strong></td>
<td><strong>0.6±0.3</strong></td>
<td><strong>22.4±0.8</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Means</strong></td>
<td><strong>6.7±1.2</strong></td>
<td></td>
<td></td>
<td><strong>0.9±2.0</strong></td>
<td><strong>20.0±0.4</strong></td>
<td></td>
</tr>
<tr>
<td>% below Critical</td>
<td>22%</td>
<td></td>
<td></td>
<td>15%</td>
<td>15%</td>
<td></td>
</tr>
</tbody>
</table>

[Soil Map Image](image)
Question 1:
Which is the zinc deficiency?

1. Chloride
2. Zinc
3. Copper
4. Manganese

I find television very educating.
Every time somebody turns on the set, I go into the other room and read a book.
Interspecific differences in Zinc

• Variation in responses to zinc

<table>
<thead>
<tr>
<th>More Likely to Show Zn Deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most likely</td>
</tr>
<tr>
<td>Maize, Sorghum.</td>
</tr>
<tr>
<td>Likely</td>
</tr>
<tr>
<td>Wheat, Barley, Lentil.</td>
</tr>
<tr>
<td>Less likely</td>
</tr>
<tr>
<td>Lupin, Chickpea, Fababean.</td>
</tr>
<tr>
<td>Lower still</td>
</tr>
<tr>
<td>Canola</td>
</tr>
</tbody>
</table>

• Also aware of large variations in response (Zinc efficiency)
  – Group B herbicides
  – VA Infections
  – Cold, wet soils (root growth patterns)
  – Phytosiderophore expression (and other root exudates).
    • Chickpea 50% more efficient than wheat in accessing Zn
      (Brennan et al. 2001, IPNI)
  – Little information on variation among our present wheat cv’s.
    • Gladius 21 mg/kg Zn, Yitpi 25 mg/kg Zn
# Availability of micronutrients – assess the situation

- **Factors influencing availability of micronutrients in soils**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
<th>B</th>
<th>Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH &gt; 7.0</td>
<td>---</td>
<td>---</td>
<td>--</td>
<td>---</td>
<td>**</td>
<td>++</td>
</tr>
<tr>
<td>pH &lt; 5.5</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Water-logged soil</td>
<td>+</td>
<td>--</td>
<td>+</td>
<td>+</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Drought</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>--</td>
</tr>
<tr>
<td>High humus content</td>
<td>---</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>--</td>
</tr>
<tr>
<td>High P-content</td>
<td>-</td>
<td>---</td>
<td>-</td>
<td>---</td>
<td>-</td>
<td>+++</td>
</tr>
<tr>
<td>Sand</td>
<td>---</td>
<td>---</td>
<td>--</td>
<td>---</td>
<td>--</td>
<td>-</td>
</tr>
<tr>
<td>Compaction</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

--- low availability high +++
Amount versus Availability

• It’s a chemical jungle out there
  – Plants compete for nutrients with the soil
  – Plant available Zn is largely as the divalent cation Zn\(^{2+}\)
  – Strongly adsorbed – so quite immobile

• More chemically driven
  – Forms insoluble hydroxides form (Zn(OH))\(_2\) – alkaline soils.
  – Binds with Fe/Mn oxides – acid soils
  – Binds/chelates with organic fractions

• Balance between fixation and dissolution

• Relationship to other soil nutrients
  – S, P and Ca all lower grain Zn.
Soil tests for Zn

- DTPA Zn (EDTA Zn)
- Critical value depends on pH, Clay, OC% (Brennan 1992)
  \[ 0.041 + 0.019*pH_{Ca} + 0.003\%\text{Clay}\% + 0.004*\text{OrganicC} \]

- In most soils this comes out less than 0.4 mg/kg.
**Tissue testing**

- Nutrient mobility
- Zn symptoms appear in younger leaves (i.e., low mobility)
- Conditions at sampling
- Tissues to sample
- Timing of sampling – early better, but still recovery from early Zn stress

<table>
<thead>
<tr>
<th>Sampling Time</th>
<th>Tissue</th>
<th>Critical or deficient Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 days after emergence</td>
<td>Whole Shoot</td>
<td>&lt;15-25 mg/kg</td>
</tr>
<tr>
<td>Mid-Late Tillering</td>
<td>Youngest expanded blade</td>
<td>&lt;14 mg/kg</td>
</tr>
<tr>
<td>Mid-Late Tillering</td>
<td>Youngest emerged blade</td>
<td>&lt;16 mg/kg</td>
</tr>
<tr>
<td>Mid-Late Tillering</td>
<td>Whole shoot</td>
<td>&lt;9 mg/kg</td>
</tr>
<tr>
<td>Maturity</td>
<td>Grain</td>
<td>&lt;15 mg/kg</td>
</tr>
<tr>
<td>Compound</td>
<td>Zinc Content</td>
<td>Formula</td>
</tr>
<tr>
<td>---------------------------</td>
<td>--------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Zinc Sulfate monohydrate</td>
<td>36%</td>
<td>ZnSO₄·H₂O</td>
</tr>
<tr>
<td>Zinc Sulfate heptahydrate</td>
<td>22%</td>
<td>ZnSO₄·7H₂O</td>
</tr>
<tr>
<td>Zinc Oxysulfate</td>
<td>20-50%</td>
<td>xZnSO₄·xZnO</td>
</tr>
<tr>
<td>Zinc Chloride</td>
<td>50%</td>
<td>ZnCl₂</td>
</tr>
<tr>
<td>Zinc Nitrate</td>
<td>23%</td>
<td>Zn(NO₃)₂·3H₂O</td>
</tr>
<tr>
<td>Zinc Oxide</td>
<td>50-80%</td>
<td>ZnO</td>
</tr>
<tr>
<td>Zinc Phosphate</td>
<td>50%</td>
<td>Zn₃(PO₄)²</td>
</tr>
<tr>
<td>Zinc Fritts</td>
<td>10-30%</td>
<td>fritted glass</td>
</tr>
</tbody>
</table>

- Ammoniated zinc sulfate 10% Zn(NH₄)SO₄ Solution | High | 

Sodium Zinc EDTA 9-13% Na₂ZnEDTA | High | High |

Lignosulfates, organic materials

- Straights – as seed dressing.
- Straights – in blends.
- Fluid blends.
- Compounded (usually on P).
- Foliar
- Enhanced seed content
At sowing or as foliar?

- Effectiveness & residual value
- Generally foliar is more efficient than at seeding (2 * removal/application)
  - <1% Zn soil applied is from fert.
  - So - need more at seeding than as a foliar (but not 100*)
- Cost per kg nutrient
  - Cost per t/(%Zn*%Efficacy*10)
- Supplements, adjuvants, magic potions.
  - Need proper data on the efficacy – field trials.

Ignoring more frequently begets confidence than does knowledge.
— Charles Darwin

<table>
<thead>
<tr>
<th>Species</th>
<th>Foliar</th>
<th>Soil</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter wheat</td>
<td>~1 kg Zn/ha</td>
<td>&gt;5 kg Zn/ha</td>
<td>Duncan, 1967a</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>2-29</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Winter wheat</td>
<td>16</td>
<td>39</td>
<td>Takkar 1989</td>
</tr>
</tbody>
</table>

% response over control
Zinc Foliar Source Application

- Compared chelate and sulfate at different times
- Chelate 1.48-1.57 * Sulfate early.
- Later they were the same.

- **Zinc at sowing was most effective!**

Brennan, 1991, AJEA
Getting it into the Right Place

Assuming normal granule size and broadcast at 2 kg Zn/ha (heptahydrate), there would be about 22 Zn granules per sq. m soil - unlikely plant roots would “see” this Zn easily

CO-GRANULATED

Assuming normal granule size, 1% Zn in o-granulated product and broadcast at 2 kg Zn/ha, there would be about 500 Zn granules per sq. m soil - much more likely plant roots would “see” this Zn
Co-granulation of TE with NPK(S) is essential

MAP+S+Zn blend

MAP+S+Zn co-granulated
Relative efficiency of zinc carriers – SSP/MAP/DAP

<table>
<thead>
<tr>
<th>Zinc Source</th>
<th>RE Crop#1</th>
<th>RE Crop#2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZnSO₄ solution</td>
<td>1.00</td>
<td>0.64</td>
</tr>
<tr>
<td>ZnSO₄ granules</td>
<td>0.12</td>
<td>0.61</td>
</tr>
<tr>
<td>SSP powder</td>
<td>0.93</td>
<td>0.61</td>
</tr>
<tr>
<td>SSP granules</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>MAP powder</td>
<td>0.78</td>
<td>0.68</td>
</tr>
<tr>
<td>MAP granules</td>
<td>0.11</td>
<td>0.12</td>
</tr>
<tr>
<td>DAP powder</td>
<td>0.95</td>
<td>0.63</td>
</tr>
<tr>
<td>DAP granules</td>
<td>0.03</td>
<td>0.06</td>
</tr>
</tbody>
</table>

- Distribution is important – particle size
- Carrier is important
  - Zn Phosphate
- Alkaline v acidic environment
Zinc at sowing – Soil pH

- Used a straights – incorporated
- Sulfate & Oxide same in acid soils, sulphate better in alkaline soils.
- *Despite solubility differences between products.*

Brennan, 1991, AJEA
Zinc reactions from the carrier granule -

- Central granule in soil.
- Pink colour shows the spread of Zn
- Diffusion volume = capacity of root interception

Zn sulfate          MOP/Zn          DAP/Zn

F deGryse et al. ASA 2012
Three soils compared

Kangaroo Island (pH 4.6)

Monarto (pH 7.0)

Pt Kenny (pH 8.0)

ZnSO₄ > MAP > DAP

ZnSO₄ > MAP > DAP

ZnSO₄ > MAP > DAP
Options to protect Zn from precipitation

New trace element fertilisers

- Physically protect TE from phosphate
- Chemically protect TE from phosphate
- Change granule chemistry
- Fluid fertilizers

[Image of a man]

[Logos of The University of Adelaide, GRDC, Mosaic, National Research Flagships, CSIRO, and IPNI]
Physical barriers to improve efficiency

Ammonium phosphate

\[ \downarrow \]

Barrier Coating

\[ \downarrow \]

Trace element

Zinc solubility in coated products

Chelates to improve TE effectiveness

Chelation BUT be wary of chelate type

Not taken up by roots

\[ \text{Zn}^{2+} + \text{EDTA}^{4-} \rightleftharpoons \text{ZnEDTA}^{2-} \]
“New” chelates to improve TE effectiveness

- **Rhamnolipid (RH)** – produced by bacteria, can diffuse easily across plant root membranes

- **Polyethylenimine (PEI)** – polymer with high Zn-complexing ability


Response of wheat to additions of rhamnolipid

Rhamnolipid (mg/kg). All pots 2ppm Zn
Response of canola to additions of Zn-PEI in fluid P fertiliser
Release of Zn from products varies with granule chemistry
Improving TE fertilizer efficiency – fluid fertilizer field trials

Summary and take home

• There are areas where zinc will give benefits.
  – Sometimes it is obvious but it is not needed every crop.

• Alone, the tools for identifying those areas are not so good.

• Products on the market vary in efficiency and price.
  – Demand that information from the supplier – from proper trials.
  – At sowing requires more product (less efficient)
  – New products coming that will increase efficiency (cost?)
  – Foliar is generally more expensive per kg supplied, but more efficient.

  – $ for $ - do the sums
    • At sowing 2 kg @ $3/kg = $6/ha (no application + residual)
    • Foliar 0.5 kg @ $10/kg = $5/ha (+application no residual)